*Virginia Department of Environmental Quality*

# Benthic Total Maximum Daily Load (TMDL) Development for the North Creek Watershed

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**June 2014**

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# Executive Summary

This report addresses the development of the benthic TMDL for the North Creek watershed in Fluvanna County, Virginia. One segment (305(b) ID: VAC-H20R_NOR01A02; Cause Group Code: H20R-02-BEN) of North Creek has been listed as impaired on Virginia's 305(b)/303(d) Water Quality Integrated Report for not meeting Virginia's General Standard.

## Description of the Study Area

The benthic impaired segment of North Creek is located within the borders of Fluvanna County and is a tributary of the James River, which discharges into the Chesapeake Bay. The major road that runs north to south along the watershed is US Highway 15. Close to the watershed's boundaries are the communities of Fork Union and Palmyra.

## Impairment Description

There is only one segment (VAC-H20R_NOR01A02) of North Creek listed as benthic impaired on Virginia's 2012 305(b)/303(d) Water Quality Integrated Report, since *"DEQ's General Standard (VR680-21-01.2) is not met for the protection of aquatic life"*. The impaired benthic segment is 3.32 miles in length, extending from the headwater to the confluence with the first unnamed tributary.

## Applicable Water Quality Standard

Water quality standards consist of designated uses for a waterbody and the water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (VA DEQ, 2007):

> *"'water quality standards' means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

## Watershed Characterization and Environmental Monitoring

The 3.32 mile benthic impaired segment within the North Creek watershed covers 2,555 acres and the larger North Creek watershed covers 4,750 acres. The watershed is located in the Bear Garden Creek – James River HUC (020802031502). The land use characterization for the North Creek TMDL watershed was based on the latest available land cover data from the National Land Cover Dataset, also known as NLCD 2006 Land Use Dataset. Dominant land uses in the watershed are forest and agriculture.

Environmental monitoring efforts in the North Creek watershed include benthic community sampling and analysis and water quality sampling and analysis. Monitoring efforts used in this TMDL were conducted by VA DEQ at four stations along the mainstem of North Creek. Biomonitoring surveys were conducted biannually between 1999-2001 and then again from 2007 and 2013. Water quality data for dissolved oxygen, pH, temperature, specific conductance, BOD, total suspended solids (TSS), turbidity, ammonia, nitrate, nitrite, total nitrogen, ortho-phosphorus, and total phosphorus, were analyzed between 2005 and 2013 using the Virginia Water Quality Standards.

There are two permitted facilities currently active in the North Creek watershed. They are both sewage treatment plants servicing the Fork Union Military Academy, and Envoy at the Village, a retirement community.

## Stressor Identification

The primary stressors causing the benthic impairment in North Creek were identified based on evaluations of candidate stressors that potentially could be impacting the stream. Based on the stressor identification analysis, the most probable stressors for the benthic community of North Creek were identified as total phosphorus enrichment and excessive sediment. Potential sources of total phosphorus and sediment in the watershed include point and nonpoint sources.

Improvement of the benthic invertebrate community in North Creek is dependent upon reducing both point and nonpoint sources of total phosphorus and sediment loading to the stream. These measures should serve to improve benthic habitat and subsequently restore macroinvertebrate populations in the stream. Therefore, a sediment and a total phosphorus (TP) TMDL were developed for North Creek.

## Endpoint Determination

VA DEQ has not adopted a numeric standard for sediment or for TP in free flowing streams. Therefore, for sediment a reference watershed near North Creek, Holiday Creek, was selected to determine the endpoint. For TP, the lowest TP value measured at a monitoring station on the lower portion of North Creek was selected as the endpoint.

## Pollutant Loading Determination

Sediment and total phosphorus sources within the benthic impaired North Creek watershed include both point and nonpoint sources. Nonpoint sources include total phosphorus and sediment from agricultural and urban runoff.

Sediment and total phosphorus loads were determined for the impaired watershed in order to quantify the reductions necessary to achieve the designated aquatic life use for North Creek. Sediment and total phosphorus loadings from land areas were estimated using the Generalized Watershed Loading Functions (GWLF) model. GWLF model simulations were performed for an 8 year simulation period (2002 to 2010) to account for both seasonal and annual variations in hydrology and sediment/total phosphorus loading.

## TMDL Calculations

Sediment and total phosphorus TMDL allocations for the North Creek impaired watershed were based on the following equation.

$$TMDL = WLA + LA + MOS$$

Where:

TMDL = Total Maximum Daily Load (Based on the area-adjusted reference watershed total phosphorus load)

WLA = Waste Load Allocation (total phosphorus loading from point sources and future growth of point sources)

LA = Load Allocation (total phosphorus loading from nonpoint sources)

MOS = Margin of Safety

In the sediment TMDL, an explicit margin of safety of 10% was used for North Creek to account for uncertainties in the methodologies used to determine sediment loadings.

In the TP TMDL, an implicit margin of safety was used for North Creek because the assumptions made in the development of the TMDL and the selection of the endpoint was conservative.

**Waste Load and Load Allocations**

Load allocation is applied to the land based sediment and total phosphorus loads in the watershed, and an equal percent reduction is required from all controllable land sources (ie agricultural and developed lands). Loads from forests, grassland/herbaceous, scrub/shrub and groundwater are considered to be representative of the natural condition and, therefore, were not subject to reductions.

The total sediment load, sediment waste load allocations, margin of safety for North Creek are summarized in **Tables E-1** and **E-2** the allocated sediment loads and the percent reduction required for all watershed sources are presented in **Table E-3**.

**Table E-1: Sediment TMDL for North Creek (ton/year)**

| Wasteload Allocation[1] | Load Allocation | Margin of Safety (10%) | TMDL |
|---|---|---|---|
| 7.29 | 76.13 | 9.27 | 92.69 |

[1]Wasteload allocation includes 2% of the TMDL for Future Growth

**Table E-2: Sediment TMDL for North Creek (ton/day)**

| Wasteload Allocation[1] | Load Allocation | Margin of Safety (10%) | TMDL |
|---|---|---|---|
| 0.020 | 0.209 | 0.025 | 0.25 |

[1]Wasteload allocation includes 2% of the TMDL for Future Growth

**Table E-3: TMDL Sediment Allocations in North Creek**

| Source | Land Use Type | Existing (tons/year) | Allocated (tons/year) | Percent Reduction |
|---|---|---|---|---|
| Land Sources | Grassland/Herbaceous | 3.83 | 3.83 | 0.0% |
| | Deciduous Forest | 29.19 | 29.19 | 0.0% |
| | Evergreen Forest | 7.31 | 7.31 | 0.0% |
| | Mixed Forest | 1.84 | 1.84 | 0.0% |
| | Pasture/Hay | 41.74 | 23.88 | 42.8% |
| | Cultivated Crop | 4.38 | 2.51 | 42.8% |
| | Developed, Low intensity | 0.59 | 0.34 | 42.8% |
| | Developed, Med Intensity | 1.30 | 0.74 | 42.8% |
| | Developed, High Intensity | 0.83 | 0.48 | 42.8% |
| | Developed, Open Space | 0.19 | 0.11 | 42.8% |
| **Instream Erosion** | - | | 5.90 | 42.8% |
| **Point Sources** | Point Source Sediment | 0.30 | 5.44 | 0.0% |
| | Future Growth (2% of the TMDL) | - | 1.85 | - |
| **Margin of Safety** | 10% of the TMDL | - | 9.27 | - |
| | **Total** | **101.83** | **92.69** | **9.0%** |

The total phosphorus load, total phosphorus waste load allocations, and margin of safety for North Creek are summarized in **Tables E-4** and **E-5** the allocated phosphorus loads and the percent reduction required for all watershed sources are presented in **Table E-6**.

| **Table E-4: Total Phosphorus TMDL for North Creek (lbs/year)** | | | |
|---|---|---|---|
| **Wasteload Allocation[1]** | **Load Allocation** | **Margin of Safety** | **TMDL** |
| **187.3** | **238.7** | **IMPLICIT** | **426.0** |
| [1]Wasteload allocation includes 2% of the TMDL for Future Growth | | | |

| **Table E-5: Total Phosphorus TMDL for North Creek (lbs/day)** | | | |
|---|---|---|---|
| **Wasteload Allocation[1]** | **Load Allocation** | **Margin of Safety** | **TMDL** |
| **0.513** | **0.654** | **IMPLICIT** | **1.167** |
| [1]Wasteload allocation includes 2% of the TMDL for Future Growth | | | |

**Table E-6: TMDL Total Phosphorus Allocations in North Creek**

| Source | Land Use Type | Existing (lbs/year) | Allocated (lbs/year) | Percent Reduction |
|---|---|---|---|---|
| Land Sources | Grassland/Herbaceous | 6.8 | 6.8 | 0.0% |
| | Deciduous Forest | 20.5 | 20.5 | 0.0% |
| | Evergreen Forest | 4.4 | 4.4 | 0.0% |
| | Mixed Forest | 0.9 | 0.9 | 0.0% |
| | Pasture/Hay | 132.5 | 29.4 | 77.8% |
| | Scrub/Shrub | 5.3 | 5.3 | 0.0% |
| | Cultivated Crop | 1.3 | 0.3 | 77.8% |
| | Developed, Low Intensity | 6.4 | 1.4 | 77.8% |
| | Developed, Med Intensity | 14.3 | 3.2 | 77.8% |
| | Developed, High Intensity | 8.6 | 1.9 | 77.8% |
| | Developed, Open Space | 75.0 | 16.6 | 77.8% |
| **Groundwater** | - | 148.0 | 148.0 | 0.0% |
| **Point Sources** | Point Source TP | 361.1 | 178.8 | 50.5% |
| | Future Growth (2% of the Total Allocated Load) | - | 8.5 | - |
| | **Total** | **785.1** | **426.0** | **45.7%** |

## Implementation

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

## Public Participation

Watershed stakeholders had opportunities to provide input and participate in the development of the TMDL during two public meetings held in the watershed. The first meeting was held at the Central Virginia Community Health Center, in New Canton Virginia, on April 7$^{th}$, 2011, the second at the Arvonia Firehouse in Arvonia, Virginia on October 7$^{th}$ 2011. Following model revisions in early 2014, a final public comment period spanning April 7$^{th}$, 2014 to May 7$^{th}$, 2014 was held. No comments were received.

# 1.0 Introduction

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's Water Quality Planning and Management Regulations (codified at Title 40 of the Code of Federal Regulations [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that do not meet water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without exceeding water quality standards. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for any uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

$$\text{TMDL} = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

Total Maximum Daily Load (TMDL) development for aquatic life use impairments due to poor health in the benthic biological community requires a methodology to identify the causes of impairment and to determine pollutant reductions that will allow streams to attain their designated uses. The identification of the pollutant(s), or stressor(s), responsible for the impaired biological communities is an important first step in developing a TMDL that accurately specifies the pollutant load reductions necessary for the stream to comply with Virginia's Water Quality Standards (9 VAC 25-260).

The first section of this report presents the regulatory guidance and defines the applicable water quality criteria for biological impairment. In subsequent sections, watershed and environmental monitoring data collected on North Creek are presented and discussed.

Stressors which may be impacting the creek are then analyzed in the stressor identification section. Based on this analysis, potential stressors impacting benthic macroinvertebrate communities in the creek are identified. In the final sections of the report, a TMDL(s) is developed and presented for the stressor(s) identified as the primary source(s) of biological impairment in North Creek.

## 1.1 Regulatory Framework

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that do not meet water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without exceeding water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and instream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollutant loadings from both point and non-point sources to restore and maintain the quality of their water resources (USEPA, 2001).

The Virginia Department of Environmental Quality (VADEQ) is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. VADEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. VADEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA), passed by the Virginia General Assembly in 1997, and coordinates public participation throughout the TMDL development process.

Within the context of the TMDL program, until recently a primary role of DCR was to regulate stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the Virginia Stormwater Management Program

(VSMP). As of July 1, 2013, these two stormwater regulatory programs are administered by DEQ. DEW also manages the important role of initiating non-point source pollution control programs statewide through the use of federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for bacteria, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (VADEQ, 2001).

As required by the Clean Water Act (CWA, 1972) and WQMIRA, VADEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters (303(d) List). In addition to 303(d) List development, the CWA requires DEQ to develop Total Maximum Daily Loads (TMDLs) for all impaired water bodies. Once TMDLs have been developed, they are distributed for public comment and then submitted to the State Water Control Board, SWCB, and USEPA for approval. WQMIRA directs VADEQ to develop and implement TMDLs for listed waters (VADEQ, 2000).

## 1.2 Impairment Listing

Segment VAC-H20R_NOR01A0 of North Creek was first listed as benthic impaired on Virginia's 2008 303(d) Total Maximum Daily Load Priority List and Reports (VADEQ, 2010) due to poor health in the benthic biological community. The 2008 TMDL Priority List and report describes the severity and need for TMDLs on surface waters in Virginia based on conditions from 2001 through 2006. This segment was also included on subsequent Virginia 303(d) Reports on Impaired Waters and Virginia 305(b)/303(d) Water Quality Integrated Assessments (VADEQ 2011, 2013). North Creek is located in the central region of Virginia, within Fluvanna County, and empties into the James River (USGS Cataloging Unit 02080203). While North Creek's impaired segment is 3.32 miles in length, the watershed boundary for one of the TMDLs is extended further to the confluence of South Creek.

Based on monitoring data for the 2012 Water Quality Assessment (2005 – 2010) at stations 2-NOR003.59 and 2-NOR003.28 the segment was found not to be supporting the standard of propagation and growth of aquatic life. **Table 1-1** summarizes the details of the impaired segments.

**Table 1-1: Impairment Summary for North Creek(VAC-H20R-02-BEN)**

| Cause Group Code | Assessment Unit | Stream Name | Length (miles) | Boundaries | Listing Station IDs: | Impairment for | TMDL Developed for |
|---|---|---|---|---|---|---|---|
| VAC-H20R-02-BEN | VAC-H20R_NOR01A02 | North Creek | 3.32 | North Creek from headwaters to the first unnamed tributary confluence | 2-NOR003.59 and 2-NOR003.28 | Benthic Macroinvertebrates | Phosphorus |
| VAC-H20R-02-BEN | VAC-H20R_NOR01A02 | North Creek | 3.32 | North Creek from headwaters to the confluence with South Creek | 2-NOR003.59 and 2-NOR003.28 | Benthic Macroinvertebrates | Sediment |

## 1.3 Applicable Water Quality Standard

Water quality standards include designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term 'water quality standards' is defined as:

> *"...provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect public health or welfare, enhance the quality of water, and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

### 1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

*"...all state waters, are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

Based on the biological assessment surveys conducted on the stream, the listed segments of North Creek defined in Section 1.2 do not support the propagation and growth of aquatic life.

### 1.3.2 Water Quality Criteria

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states:

> *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

The biological assessments conducted on North Creek indicate that some pollutant(s) are interfering with attainment of the General Standard, as impaired macroinvertebrate communities have been observed in the listed segment of the stream. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

# 2.0 Watershed Characterization

The physical conditions of the North Creek watershed were characterized using geographic information system (GIS) coverages developed for the watershed. The purpose of the characterization was to provide an overview of the conditions in the watershed related to the benthic impairment present in the listed segment of the stream. Information contained in the watershed GIS was used in the stressor identification analysis, as well as for the subsequent TMDL development. Physical watershed features such as topography, soil types, and land use conditions were characterized. Additionally, the number and location of permitted discharge facilities and DEQ monitoring stations in the watershed were summarized. This chapter serves as an inventory of the existing conditions in the watershed that were taken into consideration at the time of the stressor analysis process. The first section reviews the characteristics of the sediment TMDL watershed, and the second section reviews the characteristics of the phosphorus TMDL watershed.

## *2.1 Sediment TMDL Watershed - Physical Characteristics*

Important physical characteristics of the North Creek Sediment TMDL watershed that may be contributing to the benthic impairment were analyzed using GIS coverages developed for the area. GIS coverages for the watershed boundary, stream network, topography, soils, land use, and ecoregion of the watershed were compiled and analyzed.

### 2.1.1 Watershed Location and Boundary

North Creek is located in the central region of Virginia, entirely within Fluvanna County, and is a tributary of the James River. The watershed is located in the Bear Garden Creek – James River HUC (020802031502). The impaired benthic segment of the North Creek (H20R-02-BEN) is 3.32 miles in length, and the watershed boundary extends from the headwaters downstream to the confluence with the South Creek (**Figure 2-1**). The watershed is approximately 4,749 acres or (7.4 square miles) in area and is bordered to the North and West by the Rivanna River Watershed.

### 2.1.2 Stream Network

The stream network for the North Creek Sediment TMDL watershed was obtained from the USGS National Hydrography Dataset (NHD, 2002). The stream network and benthic impairment segment are presented in **Figure 2-1**.

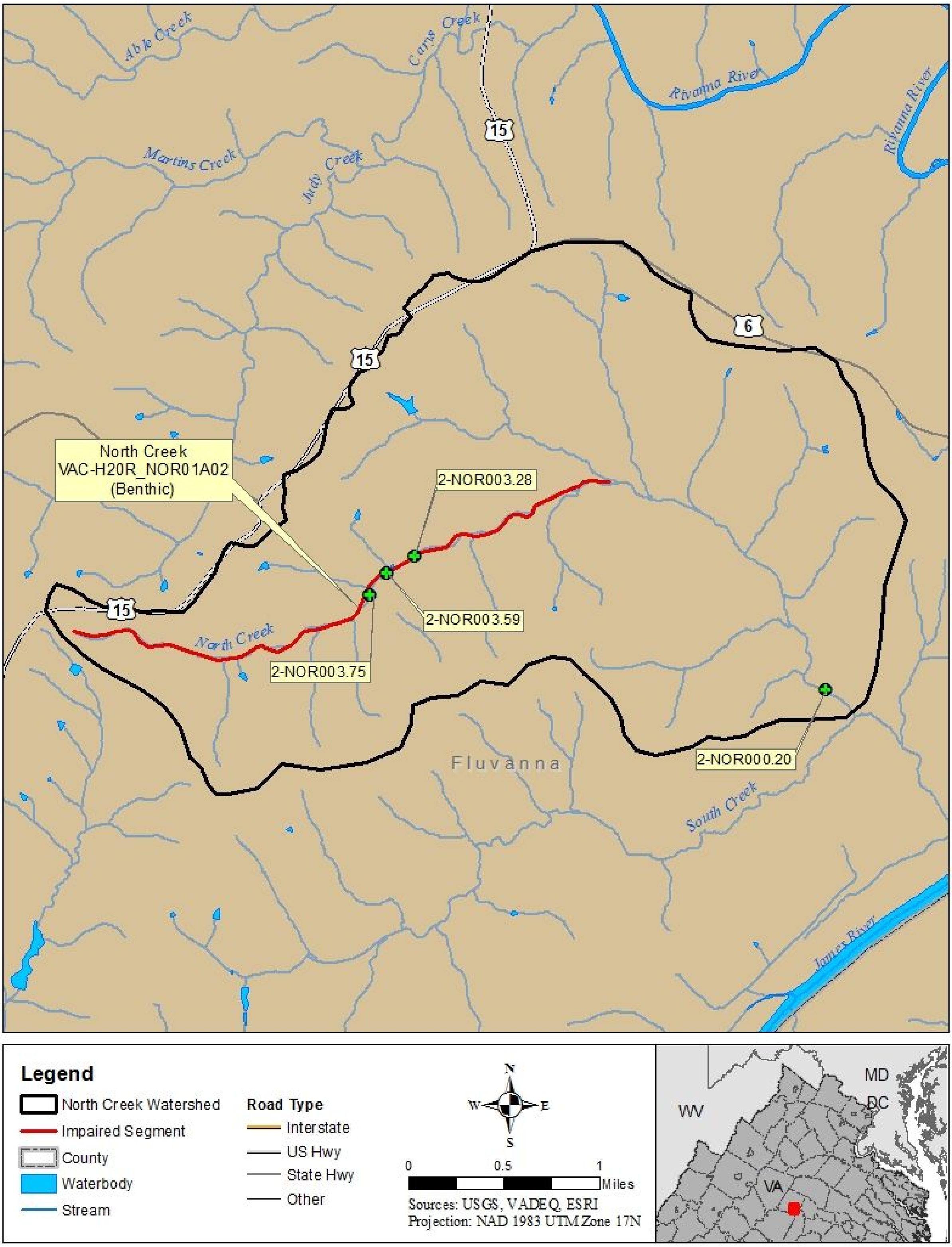



**Figure 2- 1: Stream Network and Benthic Impairment for the North Creek Sediment TMDL Watershed**

### 2.1.3 Topography

A digital elevation model (DEM) based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from the Geospatial Data Gateway maintained by the Natural Resources Conservation Service (NRCS), an entity of the US Department of Agriculture (USDA). The DEM show that elevation in the watershed ranges from approximately 199 to 474 feet above mean sea level.

### 2.1.4 Soils

The following section details soil type and hydrologic group for the North Creek Sediment TMDL watershed. The soil type characterization is based on data obtained from the Soil Survey Geographic (SSURGO) Database via *web soil survey*, a USDA program that is a multi-purpose environmental analysis system integrating GIS, national watershed data, and environmental assessment and modeling tools (NRCS, 2006). There are 22 soil types located in the watershed (**Table 2-1**). The dominant soil types within the watershed are Louisburg (43.3%) and Appling (24.5%).

**Table 2-1: Soil Types in North Creek Sediment TMDL Watershed**

| Soil type | Acres | Percent of Watershed |
|---|---|---|
| Appling | 1,165.1 | 24.5% |
| Bremo | 10.2 | 0.2% |
| Cecil | 278.2 | 5.9% |
| Colfax | 113.5 | 2.4% |
| Durham | 78.5 | 1.7% |
| Helena | 62.4 | 1.3% |
| Lignum | 1.0 | 0.0% |
| Lloyd | 5.3 | 0.1% |
| Louisburg | 2,057.5 | 43.3% |
| Made land | 24.5 | 0.5% |
| Manteo | 6.7 | 0.1% |
| Mixed alluvium | 289.2 | 6.1% |
| Nason | 50.0 | 1.1% |
| Orange | 14.9 | 0.3% |

| Table 2-1: Soil Types in North Creek Sediment TMDL Watershed | | |
|---|---|---|
| **Soil type** | **Acres** | **Percent of Watershed** |
| Rough gullied land | 8.7 | 0.2% |
| Seneca | 29.9 | 0.6% |
| Starr | 2.1 | 0.0% |
| Tatum | 105.1 | 2.2% |
| Vance | 0.6 | 0.0% |
| Water | 12.2 | 0.3% |
| Wilkes | 253.7 | 5.3% |
| Worsham | 179.9 | 3.8% |
| **Total** | **4,749.4** | **100.00%** |

The hydrologic soil groups are also based on data obtained from *web soil survey*. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well- to excessively well-drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A," soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 2-2**. The term "blank" in the hydrologic group breakdown refers to those classes defined as water.

| Table 2-2: Descriptions of Hydrologic Soil Groups | |
|---|---|
| **Hydrologic Soil Group** | **Description** |
| A | High infiltration rates. Soils are deep, well-drained to excessively drained sand and gravels. |
| B | Moderate infiltration rates. Deep and moderately deep, moderately well- and well-drained soils with moderately coarse textures. |
| B/D | Combination of Hydrologic Soil Groups B and D. |
| C | Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures. |
| C/D | Combination of Hydrologic Soil Groups C and D. |
| D | Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover. |

The major hydrologic group within the North Creek Sediment TMDL watershed is group B, with 79.5% of the watershed containing these soils. Soil hydrologic group B is defined as having moderate infiltration rates. Soils are moderately deep to deep, moderately well- to well-drained soils with moderately coarse textures. Soil hydrologic groups C, 10.5% make up the next largest portion of the watershed. Soil group C is defined as having moderate to slow infiltration rates. Soils contain layers impeding downward movement of water or soils with moderately fine or fine textures. **Table 2-3** summarizes the total percentages of hydrologic groups for the North Creek Sediment TMDL watershed.

| Table 2-3: Soil Hydrogroups in North Creek Sediment TMDL Watershed | | |
|---|---|---|
| **Soil Hydrogroup** | **Acres** | **Percent of Watershed** |
| B | 3,777.4 | 79.5% |
| B/D | 226.2 | 4.8% |
| C | 498.9 | 10.5% |
| C/D | 6.7 | 0.1% |
| D | 228.0 | 4.8% |
| (blank) | 12.2 | 0.3% |
| **Total** | **4,749.4** | **100.0%** |

### 2.1.5 Land Use

The land use characterization for the North Creek Sediment TMDL watershed was based on the 2006 National Land Cover Dataset (NLCD 2006). The distribution of land uses in the watershed, by land area and percentage, are presented in **Table 2-4**. Dominant land uses in the watershed are Deciduous Forest (58.3%), Evergreen Forest (14.6%), and Pasture/Hay (14.3%). An overview of the land use distribution is shown in **Figure 2-2**.

**Table 2-4: Land Use in the North Creek Sediment TMDL Watershed**

| General Land Use Category | NLCD 2006 Land Use Category | Acres | Total Acres | Percentage of Watershed | Total Percent |
|---|---|---|---|---|---|
| Developed | Developed High Intensity | 4.0 | 162.4 | 0.1% | 3.4% |
| | Developed Medium Intensity | 10.3 | | 0.2% | |
| | Developed Low Intensity | 18.4 | | 0.4% | |
| | Developed Open Space | 129.7 | | 2.7% | |
| Agricultural | Cultivated Crops | 6.5 | 684.8 | 0.1% | 14.4% |
| | Pasture/Hay | 678.3 | | 14.3% | |
| Forest | Deciduous Forest | 2,770.6 | 3,639.6 | 58.3% | 76.6% |
| | Evergreen Forest | 694.2 | | 14.6% | |
| | Mixed Forest | 174.7 | | 3.7% | |
| Water & Wetlands | Open Water | 12.1 | 56 | 0.3% | 1.2% |
| | Woody Wetlands | 44.3 | | 0.9% | |
| Other | Scrub/Shrub | 162.1 | 206.3 | 3.4% | 4.3% |
| | Grassland/Herbaceous | 44.2 | | 0.9% | |
| Total | | **4,749.4** | 4,749.4 | 100% | 100% |

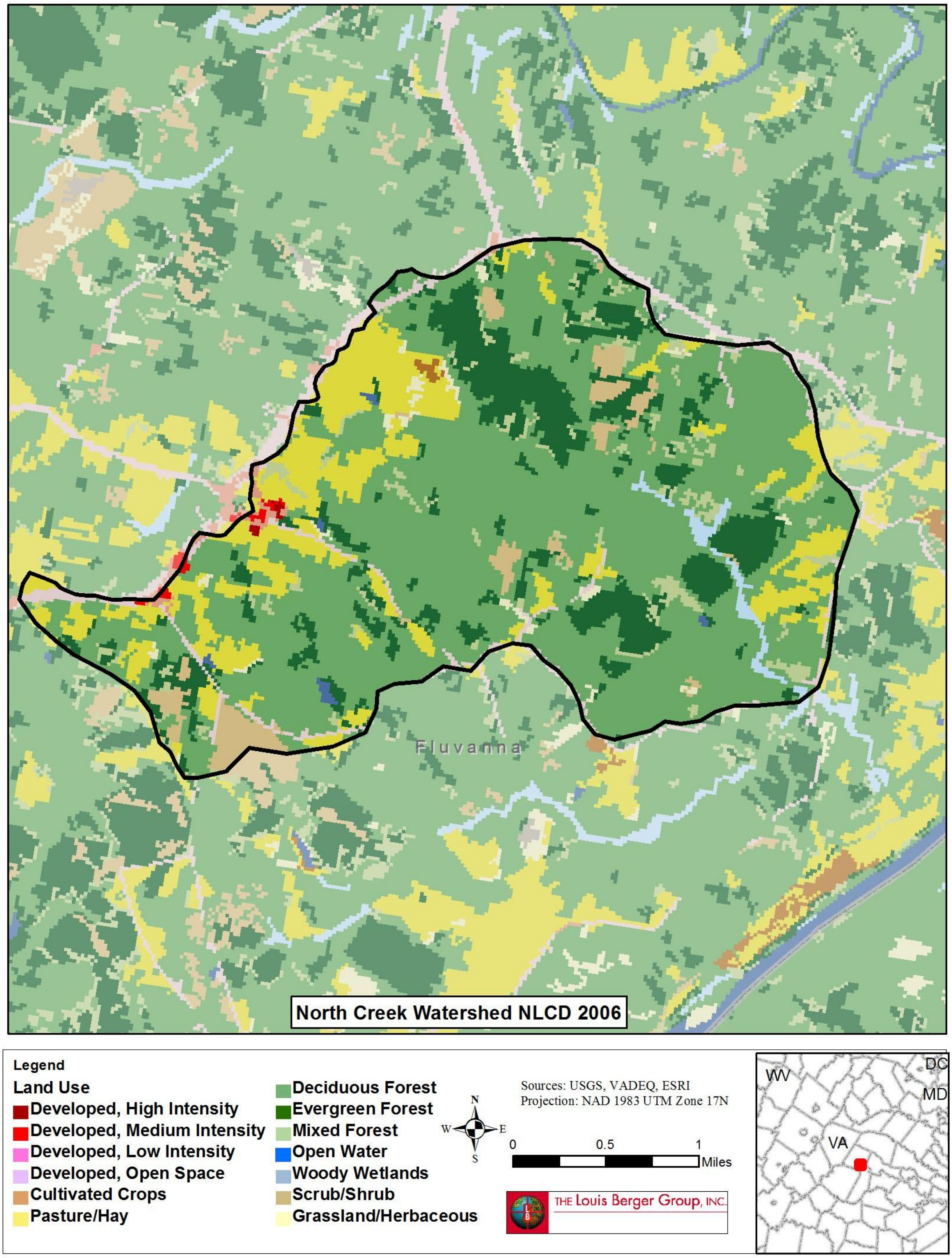



**Figure 2- 2: Land Use in the North Creek Sediment TMDL Watershed**

### 2.1.6 Ecoregion Classification

The North Creek Sediment TMDL watershed is located in the Piedmont ecoregion, USEPA Level III classification number 45 (Woods et al., 1999). The Piedmont ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia, and forms a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the flat coastal plain to the southeast. Once largely cultivated, much of this region has reverted to pine and hardwood woodlands. The Piedmont ecoregion is characterized by shallow valleys, irregular plains, and low rounded hills and ridges. The underlying geology of this region consists of deeply weathered, deformed metamorphic rocks with intrusions by igneous material.

## *2.2 Total Phosphorus TMDL Watershed - Physical Characteristics*

Important physical characteristics of the North Creek Total Phosphorus (TP) TMDL watershed that may be contributing to the benthic impairment were analyzed using GIS coverages developed for the area. GIS coverages for the watershed boundary, stream network, topography, soils, land use, and ecoregion of the watershed were compiled and analyzed.

### 2.2.1 Watershed Location and Boundary

The North Creek TP TMDL watershed is located in the central region of Virginia, entirely within Fluvanna County, and is a tributary of the James River. The watershed is located in the Bear Garden Creek – James River HUC (020802031502). The watershed is bordered to the North and West by the Rivanna River Watershed. The impaired benthic segment of the North Creek (H20R-02-BEN) is 3.32 miles in length, extending from the headwaters downstream to the confluence with the first unnamed tributary (**Figure 2-3**). The impaired watershed is approximately 2,556 acres or (3.5 square miles) in area.

### 2.2.2 Stream Network

The stream network for the North Creek TP TMDL watershed was obtained from the USGS National Hydrography Dataset (NHD, 2002). The stream network and benthic impairment segment are presented in **Figure 2-3**.

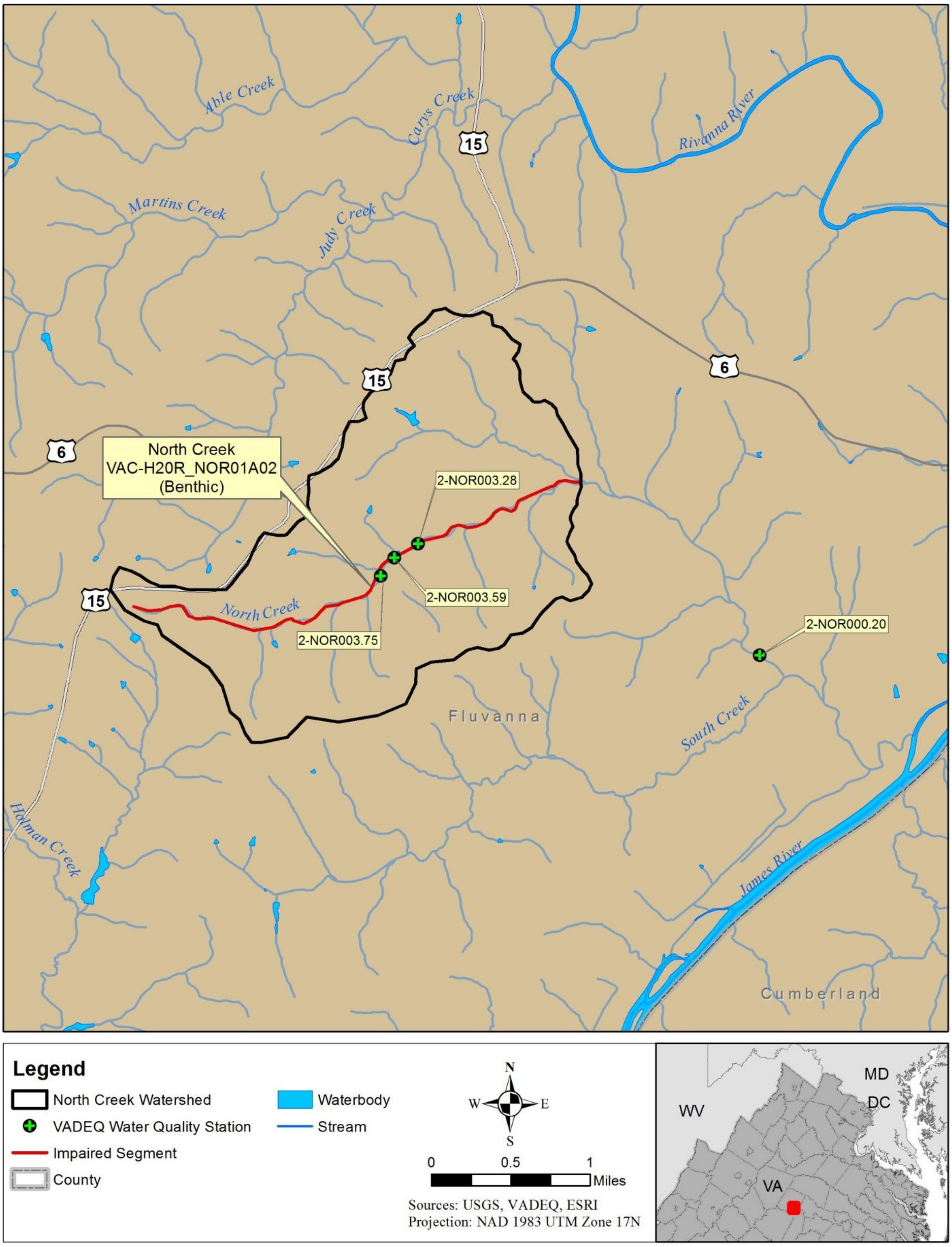



**Figure 2- 3: Stream Network and Benthic Impairment for the North Creek Phosphorus TMDL Watershed**

### 2.2.3 Topography

A digital elevation model (DEM) based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from the Geospatial Data Gateway maintained by the Natural Resources Conservation Service (NRCS), an entity of the US Department of Agriculture (USDA). The DEM show that elevation in the watershed ranges from approximately 227 to 474 feet above mean sea level.

### 2.2.4 Soils

The following section details soil type and hydrologic group for the North Creek TP TMDL watershed. The soil type characterization is based on data obtained from the Soil Survey Geographic (SSURGO) Database via *web soil survey*, a USDA program that is a multi-purpose environmental analysis system integrating GIS, national watershed data, and environmental assessment and modeling tools (NRCS, 2006). There are 19 soil types located in the watershed (**Table 2-5**). The dominant soil types within the watershed are Louisburg (35%) and Appling (32%).

**Table 2-5. Soil Types in North Creek Watershed**

| Soil Component | Acres | Percent of Watershed |
|---|---|---|
| Appling | 808.1 | 31.6% |
| Cecil | 135.5 | 5.3% |
| Colfax | 108.1 | 4.2% |
| Durham | 55.5 | 2.2% |
| Helena | 35.5 | 1.4% |
| Lignum | 1.0 | 0.0% |
| Louisburg | 895.4 | 35.0% |
| Made land | 24.0 | 0.9% |
| Manteo | 3.0 | 0.1% |
| Mixed alluvium | 127.2 | 5.0% |
| Nason | 49.3 | 1.9% |
| Orange | 10.5 | 0.4% |
| Rough gullied land | 5.5 | 0.2% |
| Seneca | 22.6 | 0.9% |
| Tatum | 102.2 | 4.0% |

| Table 2-5. Soil Types in North Creek Watershed | | |
|---|---|---|
| **Soil Component** | **Acres** | **Percent of Watershed** |
| Vance | 0.6 | 0.0% |
| Water | 12.2 | 0.5% |
| Wilkes | 0.6 | 0.0% |
| Worsham | 159.1 | 6.2% |
| **Total** | **2555.8** | 100.0% |

The hydrologic soil groups are also based on data obtained from *soil data mart*. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well- to excessively well-drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A," soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 2-6**. The term "blank" in the hydrologic group breakdown refers to those classes defined as water or urban land.

| Table 2-6: Descriptions of Hydrologic Soil Groups | |
|---|---|
| **Hydrologic Soil Group** | **Description** |
| A | High infiltration rates. Soils are deep, well-drained to excessively drained sand and gravels. |
| B | Moderate infiltration rates. Deep and moderately deep, moderately well- and well-drained soils with moderately coarse textures. |
| B/D | Combination of Hydrologic Soil Groups B and D. |
| C | Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures. |
| C/D | Combination of Hydrologic Soil Groups C and D. |
| D | Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover. |

The major hydrologic group within the North Creek TP TMDL watershed is group B, with 81.5% of the watershed containing these soils. Soil hydrologic group B is defined as having moderate infiltration rates. Soils are moderately deep to deep, moderately well- to well-drained soils with moderately coarse textures. At 7.8% and 7.6%, soil hydrologic groups D and C, respectively, make up the next largest portions of the watershed. Soil group D is defined as having very slow infiltration rates. Soil group C is defined as having moderate to slow infiltration rates. Soils contain layers impeding downward movement of water or soils with moderately fine or fine textures. **Table 2-7** summarizes the total percentages of hydrologic groups for the North Creek Watershed.

**Table 2-7: Soil Hydrogroups in North Creek TP TMDL Watershed**

| Soil Hydrogroup | Acres | Percent of Watershed |
|---|---|---|
| B | 2,082.6 | 81.5% |
| B/D | 63.8 | 2.5% |
| C | 195.1 | 7.6% |
| C/D | 3.0 | 0.1% |
| D | 199.1 | 7.8% |
| (blank) | 12.2 | 0.5% |
| **Total** | **2,555.8** | **100.0%** |

### 2.2.5 Land Use

The land use characterization for the North Creek TP TMDL watershed was based on the 2006 National Land Cover Dataset (NLCD 2006). The distribution of land uses in the watershed, by land area and percentage, are presented in **Table 2-8**. Dominant land uses in the watershed are Deciduous Forest (53.9%), Pasture/Hay (20.7%) and Evergreen Forest (12.9%). An overview of the land use distribution is shown in **Figure 2-4**.

| Table 2-8: Land Use in the North Creek TMDL Watershed | | | | | |
|---|---|---|---|---|---|
| **General Land Use Category** | **NLCD 2006 Land Use Category** | **Acres** | **Total Acres** | **Percentage of Watershed** | **Total Percent** |
| Developed | Developed High Intensity | 4.0 | 112.1 | 0.2% | 4.4% |
| | Developed Medium Intensity | 10.1 | | 0.4% | |
| | Developed Low Intensity | 18.1 | | 0.7% | |
| | Developed Open Space | 79.8 | | 3.1% | |
| Agricultural | Cultivated Crops | 6.5 | 534.9 | 0.3% | 20.9% |
| | Pasture/Hay | 528.4 | | 20.7% | |
| Forest | Deciduous Forest | 1,376.8 | 1,772.3 | 53.9% | 69.3% |
| | Evergreen Forest | 328.5 | | 12.9% | |
| | Mixed Forest | 67.1 | | 2.6% | |
| Water | Open Water | 10.5 | 10.5 | 0.4% | 0.4% |
| Other | Scrub/Shrub | 97.5 | 126.0 | 3.8% | 4.9% |
| | Grassland/Herbaceous | 28.5 | | 1.1% | |
| Total | | **2,555.8** | **2555.8** | **100%** | **100%** |

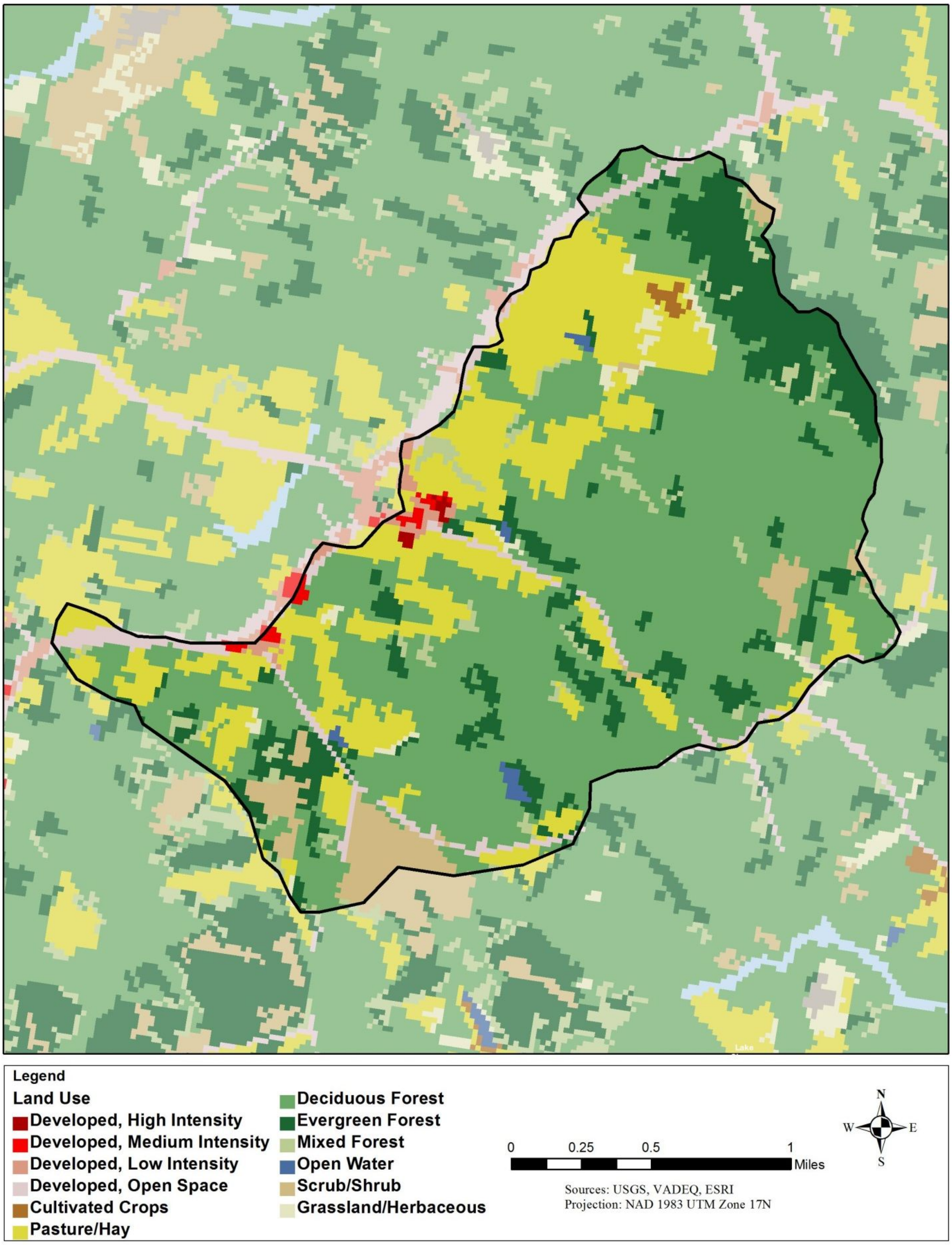



**Figure 2- 4: Land Use in the North Creek TP TMDL Watershed**

### 2.2.6 Ecoregion Classification

The North Creek TP TMDL watershed is located in the Piedmont ecoregion, USEPA Level III classification number 45 (Woods et al., 1999). The Piedmont ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia, and forms a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the flat coastal plain to the southeast. Once largely cultivated, much of this region has reverted to pine and hardwood woodlands. The Piedmont ecoregion is characterized by shallow valleys, irregular plains, and low rounded hills and ridges. The underlying geology of this region consists of deeply weathered, deformed metamorphic rocks with intrusions by igneous material.

## *2.3 Permitted Discharge Facilities*

Data obtained from the VA DEQ's Blue Ridge Regional Office (Lynchburg) indicate that there are two individual Virginia Pollutant Discharge Elimination System (VPDES) permitted facilities currently active or none under application in the North Creek watershed. The permit number, permitted flow, and receiving waterbody of the facilities holding individual permits are presented in **Table 2-9**, and their locations are presented in **Figure 2-5**. There are no general permits issued in the North Creek Watershed. There are no Municipal Separate Storm Sewer (MS4) permits issued to Cities, Towns, Counties, or other facilities within the North Creek benthic impaired watershed.

**Table 2-9: Permitted Facilities in the North Creek Watershed**

| Permit Number | Facility Name | Design Flow (MGD) | Receiving Stream |
|---|---|---|---|
| VA0081639 | Envoy at the Village | 0.02 | North Creek Tributary |
| VA0024147 | Fork Union Military Academy | 0.099 | North Creek |

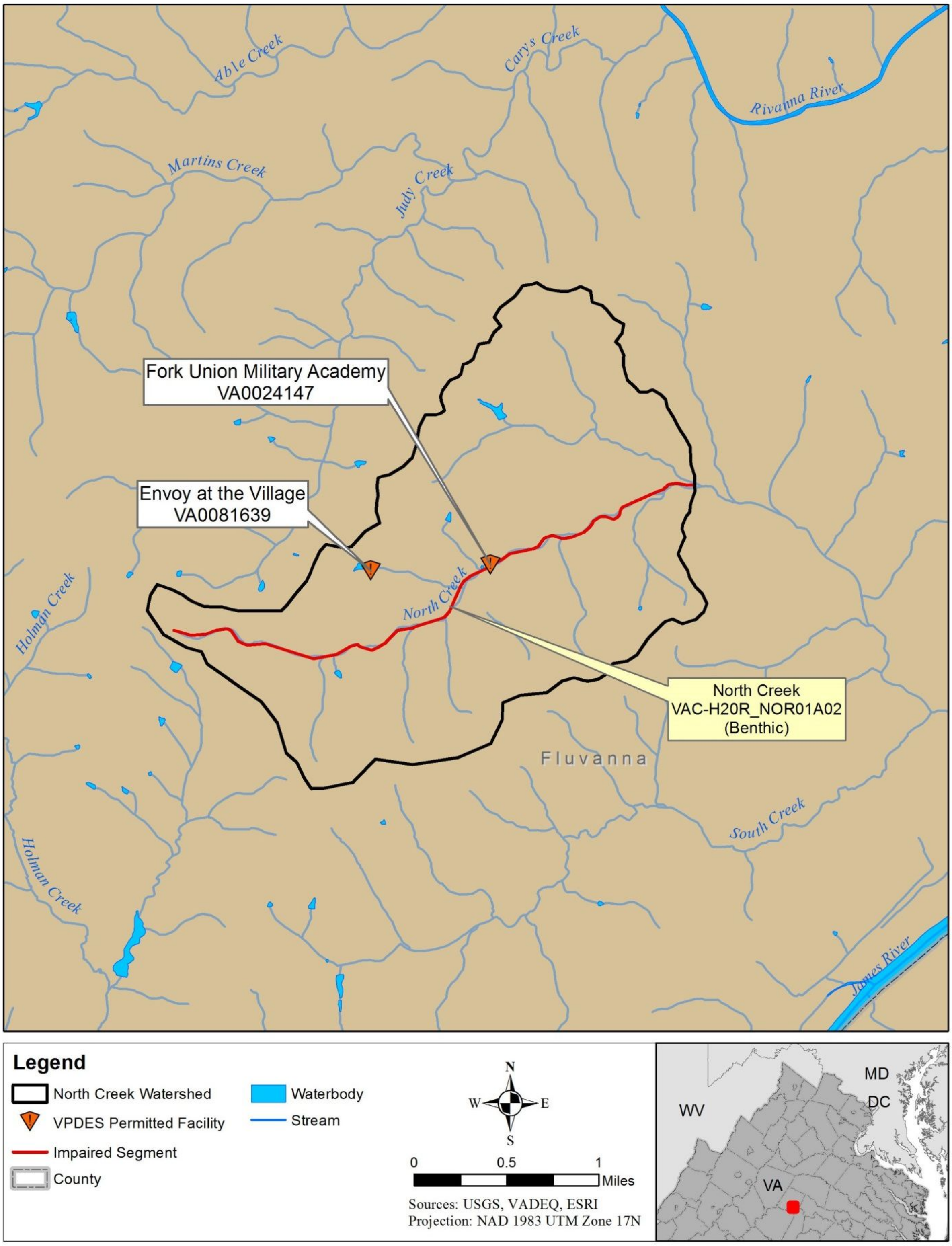



**Figure 2- 5: Location of Dischargers with Individual Permits in the Benthic Impaired North Creek Watershed**

# 3.0 Environmental Monitoring

Environmental monitoring efforts in the North Creek watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, and Discharge Monitoring Reports (DMR). Monitoring efforts presented in this chapter were conducted by VA DEQ.

## *3.1 DEQ Monitoring Stations*

VA DEQ has monitored ambient water quality, macroinvertebrate communities and sediment chemistry at four locations in the North Creek watershed. Of the four sites, three are located along the impaired segment. In addition, the two permitted facilities monitored their effluent for ambient water quality. A list of the VA DEQ and Point Source monitoring stations in the North Creek watershed is provided in **Table 3-1,** and the locations of these stations are presented in **Figure 3-1**. Station identification numbers include the abbreviated creek name and the river mile on the creek where the station is located (the river mile number represents the distance from the mouth of the creek).

**Table 3-1: North Creek Monitoring Station Summary**

| Stream | Station | Description | Available Data | Sampling Dates | | Count |
|---|---|---|---|---|---|---|
| | | | | Start | End | |
| Impaired | 2-NOR003.75 | North Creek Upstream of UT NC Confluence | Macroinvertebrates | 11/13/2012 | 3/11/2013 | 2 |
| | | | Instream chemical parameters | 2/29/2012 | 5/29/2013 | 14 |
| | 2-NOR003.59 | Upstream of F.U.M.A Discharge | Macroinvertebrates | 6/2/1999 | 3/11/2013 | 15 |
| | | | Instream chemical parameters | 6/22/2000 | 5/29/2013 | 28 |
| | 2-NOR003.28 | Below F.U.M.A. STP Discharge | Macroinvertebrates | 6/2/1999 | 3/11/2013 | 14 |
| | | | Instream chemical parameters | 6/22/2000 | 5/29/2013 | 29 |
| Non Impaired | 2-NOR000.20 | Rt. 654 bridge | Macroinvertebrates | 10/21/1999 | 3/11/2013 | 11 |
| | | | Instream chemical parameters | 7/11/2005 | 5/29/2013 | 27 |
| Point Source Monitoring | VA0024147 | F.U.M.A. STP | Instream chemical parameters | 6/6/2012 | 8/7/2012 | 6 |
| | VA0081639 | The Village Nursing Center | Instream chemical parameters | 9/4/2003 | 5/29/2013 | 14 |

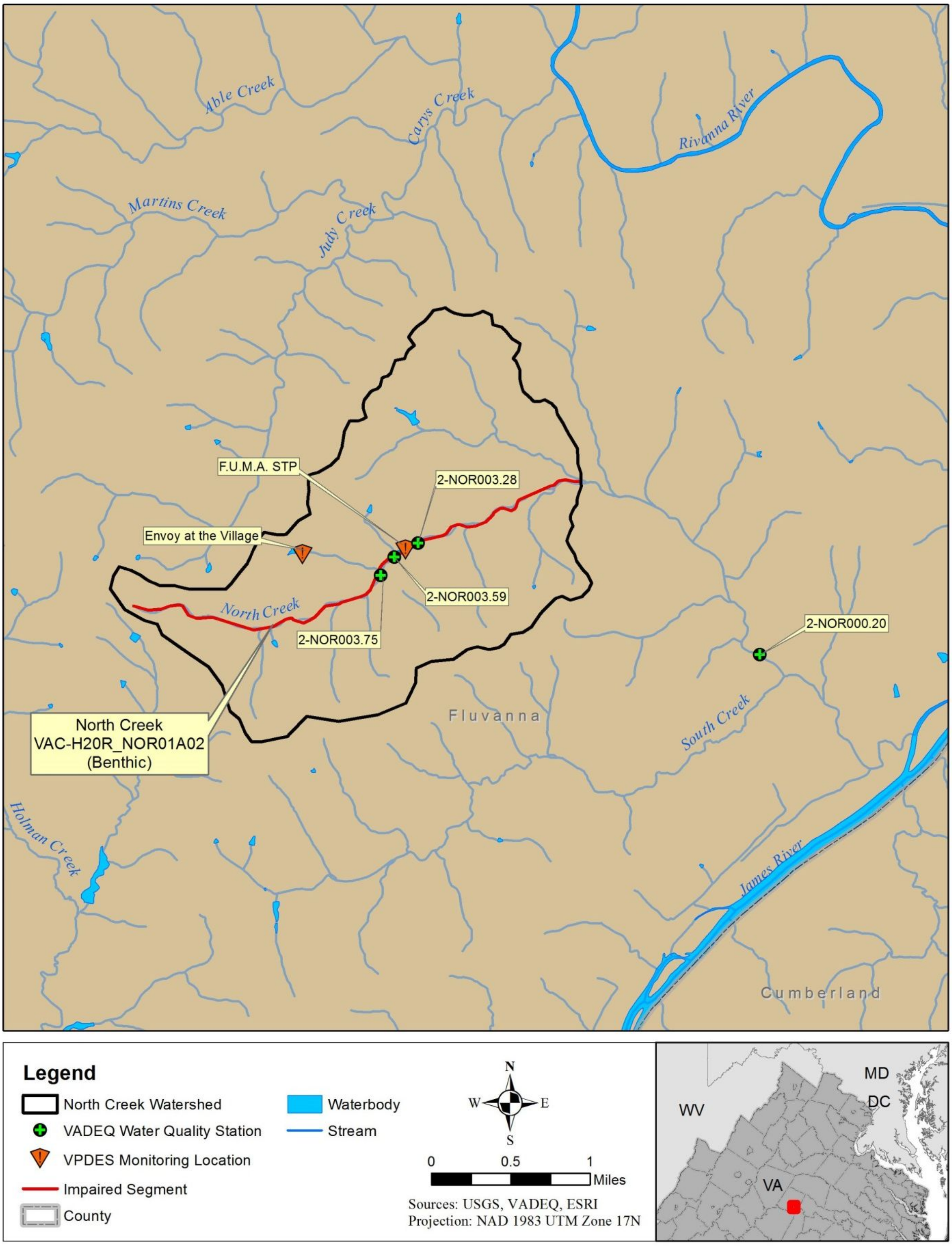



**Figure 3-1: Monitoring Stations Used in the Benthic TMDL for the North Creek Watershed**

### 3.1.1 Biological Monitoring Data

Based on biological monitoring data, a portion of North Creek was originally listed as impaired on the 2008 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community. North Creek was subsequently listed in the 2010 and 2012 Integrated 305(b)/303(d) Assessment. Biological monitoring data were collected at stations 2-NOR003.59 and 2-NOR003.28 from 1999-2001 (not monitored in spring 2001), from 2007 to 2010, and again in the Fall of 2012 and Spring of 2013. Additional biological monitoring data were collected at station 2-NOR000.20 in Fall of 1999, from 2007-2010, and again in the Fall of 2012 and Spring of 2013. A new station, 2-NOR0003.75, was added to monitor biological data in Fall of 2012 and Spring of 2013 upstream of any point source contribution.

Biological monitoring data was evaluated using the Virginia Stream Condition Index (VSCI). Calculation of a VSCI score incorporates eight standard metrics, based on the abundance and types of macroinvertebrates present at each station. The multiple metrics evaluated together give an overall indication of ecological integrity. These bioassessment scores were compared to a reference condition, which is based on an aggregate of unimpaired streams in non-coastal Virginia. The VSCI metrics and their expected response to declining stream conditions are presented in **Table 3-2**.

**Table 3-2: Metrics Used to Calculate the Virginia Stream Condition Index (VSCI)**

| Metrics | Expected Response to Disturbance | Definition of Metric |
|---|---|---|
| ***Taxonomic Richness*** | | |
| Total Taxa | Decrease | Total number of Taxa observed |
| EPT Taxa | Decrease | Total number of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa observed |
| ***Taxonomic Composition*** | | |
| % PT Less Hydropsychidae | Decrease | % PT taxa in samples, subtracting pollution-tolerant Hydropsychidae |
| % Ephemeroptera | Decrease | % Ephemeroptera taxa present in sample |
| % Chironomidae | Increase | % pollution-tolerant Chironomidae present |
| ***Balance/Diversity*** | | |
| % Top 2 Dominant | Increase | % dominance of the 2 most abundant taxa |
| ***Tolerance*** | | |
| HBI (Family level) | Increase | Hilsenhoff Biotic Index (HBI) |
| ***Trophic Group*** | | |
| % Scrapers | Decrease | % of scraper functional feeding group |

An impairment cutoff score of 60.0 is used for assessing results. Stream segments that have a VSCI score of 60 or greater are generally considered to be non-impaired, while streams that score less than 60 are generally considered impaired (VADEQ, 2010).

***VSCI Scores***

In the North Creek watershed, VSCI scores were calculated for stations 2-NOR003.75, 2-NOR003.59, 2-NOR003.28, and station 2-NOR000.20. Four sets of data were used to analyze the individual metrics at each of the three monitoring stations. These include monitoring data collected from 1999 - 2001, 2007-2008, 2009-2010, and 2012-2013. The following is a summary of the metrics used in calculating the VSCI scores.

***a) Taxonomic Richness***

Taxa richness measures the overall variety of the invertebrate assemblage by counting the number of distinct taxa within selected taxonomic groups (Burton et. al. 2003). High taxa richness is usually an indicator of a healthy benthic community. At the North Creek watershed monitoring stations, the average total taxa ranged from 11.0 to 14.8 between 1999 and 2001, 11.7 to 16.5 between 2007 and 2008, 11.0 to 17.0 between 2009 and 2010, and 13.5 to 24.0 between 2012 to 2013 (**Figure 3-2**). Over the four sets of data, there was a decrease in average total taxa from stations 2-NOR003.59 to 2-NOR003.28. Between 1999 and 2001, there was a continuing decrease in total taxa from stations 2-NOR003.28 and 2-NOR000.20. However, there was an increase in average total taxa from station 2-NOR003.28 to 2-NOR000.20 for the 2007-2008, 2009-2010, and 2012-2013 monitoring data, indicating the benthic community at these two locations are recovering.

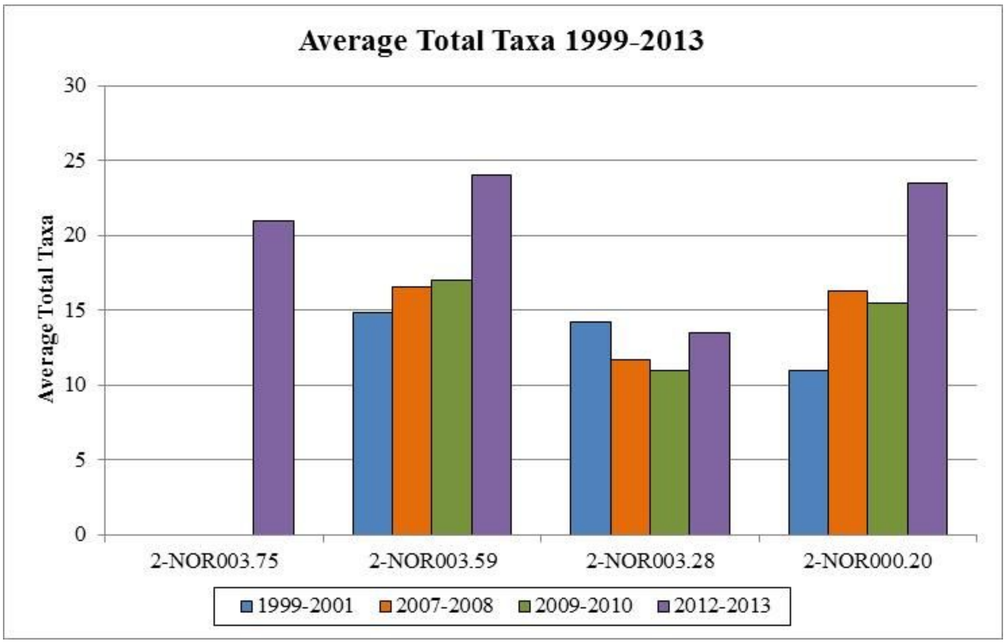



**Figure 3-2: Average Total Taxa in the North Creek Watershed**

Another metric of taxonomic richness is the EPT (Ephemeroptera - mayflies, Plecoptera - stoneflies, Trichoptera - caddisflies) index. The EPT index is the number of families from the EPT orders in a sampling. Since the majority of the families in the EPT orders are intolerant of pollution and other environmental stressors, the EPT index is another indicator of benthic community health. At the North Creek watershed monitoring stations, the EPT index ranged from 3.0 to 6.0 between 1999 and 2001, 4.7 to 9.0 between 2007 and 2008, 4.5 to 7.5 between 2009 and 2010, and 6.0 to 12.5 between 2012 and 2013 (**Figure 3-3**). Over the four sets of data EPT taxa decreased from 2-NOR003.59 to 2-NOR003.28 indicating a decline in the health of the benthic community from an upstream location to a downstream location along the impaired segment. There was an increase in the average EPT taxa from station 2-NOR003.28 to 2-NOR000.20, indicating the benthic community appeared to recover at station 2-NOR000.20. Additionally, average EPT taxa were higher at monitoring station 2-NOR000.20 than at monitoring station 2-NOR003.59 for all three data sets.

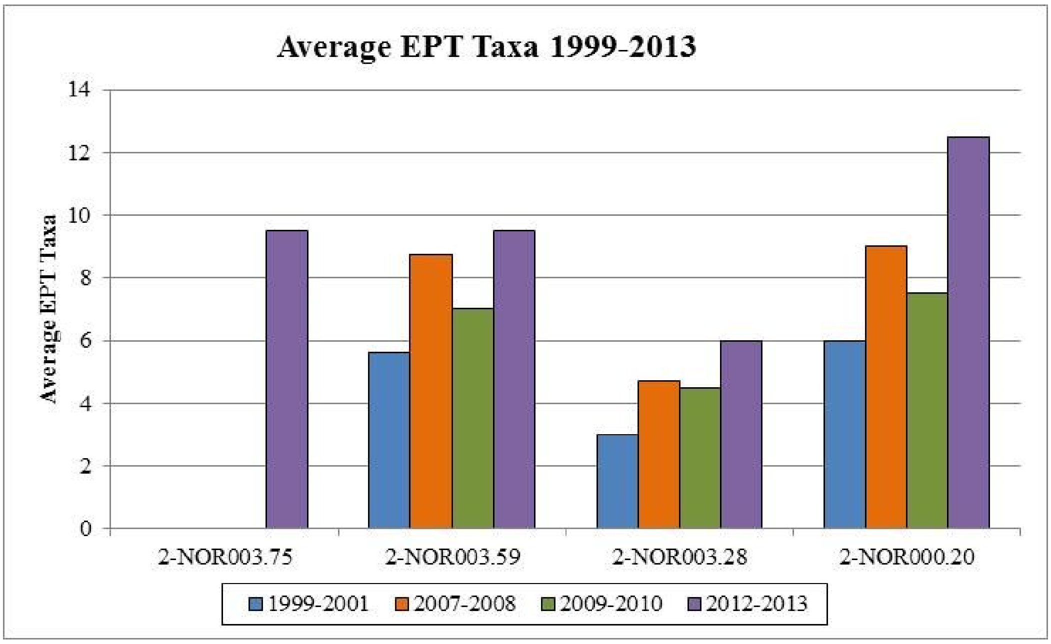



**Figure 3-3: Average EPT Taxa in the North Creek Watershed**

b) ***Taxonomic Composition***

The composition of stoneflies and caddisflies (Plecoptera and Trichoptera, respectfully), excluding the family of netspinning caddisflies - Hydropsychidae that are pollution-tolerant, were measured as an indicator of stream health. At the North Creek watershed monitoring stations, the percent PT, less Hydropsychidae, index ranged from 3.2 to 15.3 between 1999 and 2001, 3.4 to 29.6 between 2007 and 2008, 2.8 to 26.9 between 2009 and 2010, and 3.6 to 36.4 between 2012 and 2013 (Figure 3-4). From station 2-NOR003.75 to 2-NOR003.59 in 2012-2013, and over the four sets of data from stations 2-NOR003.59 to 2-NOR003.28, there was a decline in the percent PT, less Hydropsychidae indicating a decline of the benthic community from the upstream locations to the downstream locations. There was an increase in the % PT, less Hydropsychidae from station 2-NOR003.28 to 2-NOR000.20, indicating the benthic community appeared to recover at station 2-NOR000.20. Additionally, average % PT, less Hydropsychidae were higher at monitoring station 2-NOR000.20 than at monitoring station 2-NOR003.59 for all four data sets.

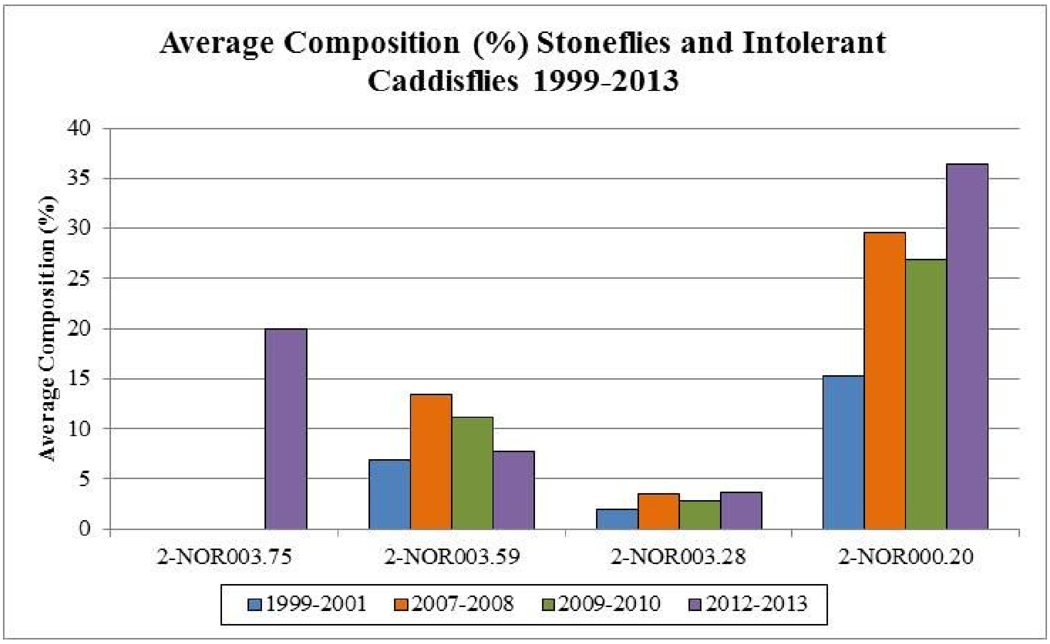



**Figure 3-4: Average Composition of Stoneflies and Intolerant Caddisflies in the North Creek Watershed**

The percentage of mayflies (Ephemeroptera) was calculated to measure the composition of mayfly nymphs within the sample. Since the majority of these species are highly sensitive to pollution and environmental stress, this metric is used as an indicator of stream health. At the North Creek watershed monitoring stations, the average percent composition of mayflies ranged from 1.4 to 12.5 between 1999 and 2001, 6.7 to 21.7 between 2007 and 2008, 5.4 to 18.8 between 2009 and 2010, and 16.4 and 23.6 between 2012 and 2013 (**Figure 3-5**). From station 2-NOR003.75 to 2-NOR003.59 in 2012-2013, and over the four sets of data from stations 2-NOR003.59 to 2-NOR003.28, there was a decrease in the average percent composition of mayflies, indicating a decline of the benthic community from the upstream locations to the downstream locations. There was an increase in the average percent composition of mayflies from station 2-NOR003.28 to 2-NOR000.20, indicating the benthic community appeared to recover at station 2-NOR000.20 . The average percent composition of mayflies was higher at monitoring station 2-NOR000.20 than at monitoring station 2-NOR003.59 for all periods but 1991 to 2001.

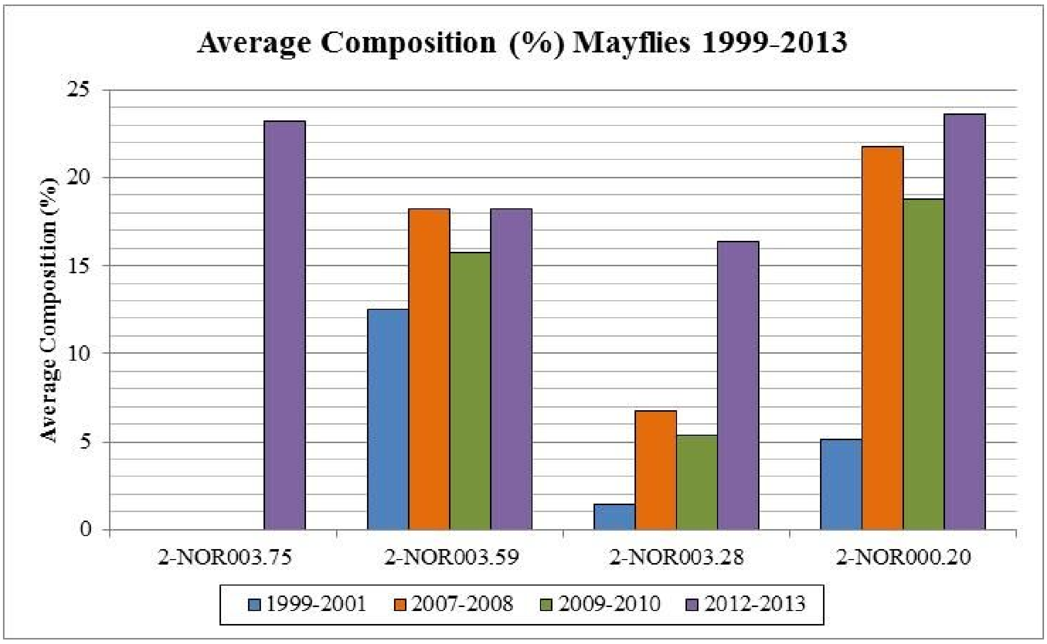



**Figure 3-5: Percent Composition of Mayfly Nymphs in the North Creek Watershed**

The percentage of midges (Chironomidae) was calculated to measure the composition of midge larvae within the sample. Because midge larvae are tolerant to many stressors, this metric is expected to increase with increasing pollution and environmental stress, thus an overall increase in midge larvae was expected from monitoring stations 2-NOR003.59 to 2-NOR003.28 followed by an overall decrease from monitoring stations 2-NOR003.28 to 2-NOR000.20 based upon the trends of other pollution intolerant species composition. The composition of midge larvae generally decreased from upstream to downstream in North Creek for 2007-2008, 2009-2010, and 2012-2013, although the composition averages from the 1999-2001 data set show a spike at monitoring station 2-NOR000.20 that was higher than both upstream monitoring stations (72.5 % compared to 49.2 % at monitoring station 2-NOR003.59 and 28.7 % at monitoring station 2-NOR003.28) (**Figure 3-6**). The composition of midge larvae at 2-NOR000.20 indicates the health of this benthic community is still in recovery. The most recent trends (2012-2013) in midge larvae composition show substantial decreases (10-20%) from each station in comparison to prior periods, indicating the impaired stream could be recovering.

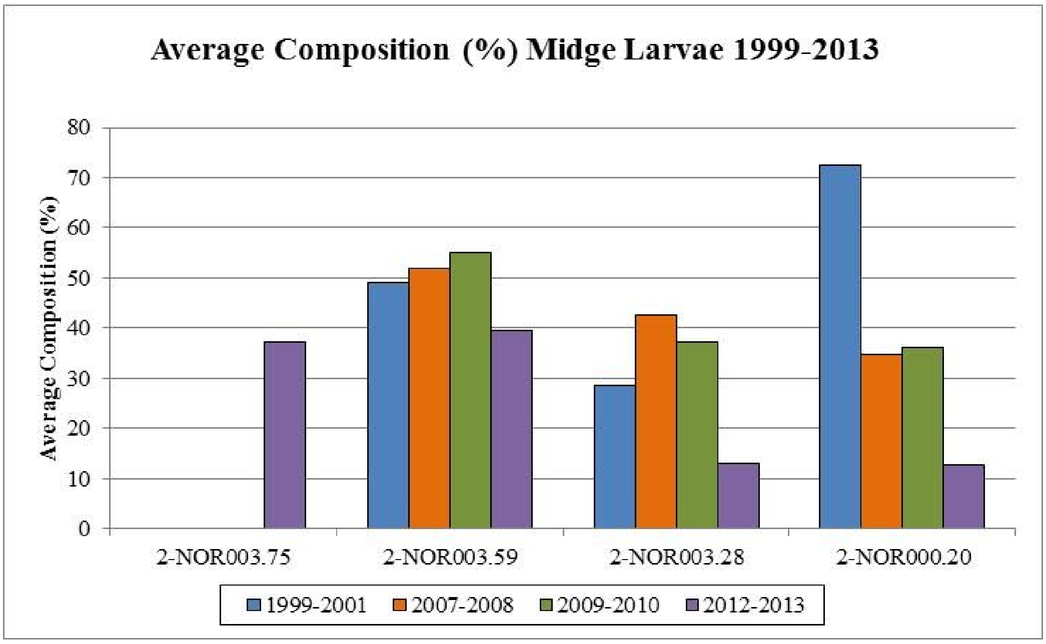



**Figure 3-6: Average Percent Composition of Midge Larvae in the North Creek Watershed**

### *c) Balance and Diversity*

The percentage of the two most abundant taxa was calculated as a measure of the community balance within the sample. As with taxa richness, a community in a polluted stream will most often be dominated by a few taxa. Generally, in the North Creek watershed samples from all stations were dominated by two taxa. The average percent composition of the two most abundant taxa ranged from 62.5 to 85.7 between 1999 and 2001, 55.4 to 76.9 between 2007 and 2008, 56.8 to 76.3 between 2009 and 2010 monitoring stations, and 47.7 and 56.4 between 2012 and 2013 (**Figure 3-7**). From station 2-NOR003.59 to 2-NOR003.28 the percentage of the two most abundant taxa increased between 2007-2008, 2009-2010; and 2012-2013 however, the 1999-2001 data shows a slight decrease. Similar to the results of the average composition of midge larva, composition averages from the 1999-2001 data set show a spike at monitoring station 2-NOR000.20 that was higher than both upstream monitoring stations (85.7 % compared to 67.1 % at monitoring station 2-NOR003.59 and 62.5 % at monitoring station 2-NOR003.28). The 2012-2013 for taxa dominance show less percent composition at each station is less than in prior data collection periods. These data indicate the health of the benthic community is still in recovery.

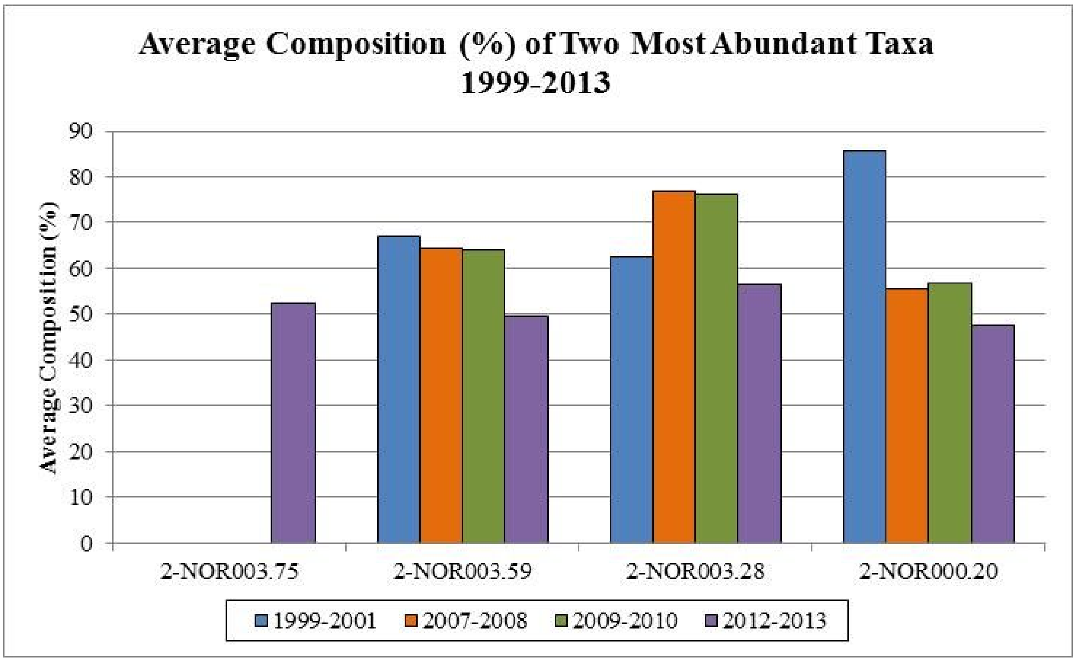



**Figure 3-7: Average Percent Composition of Two Most Abundant Taxa in the North Creek Watershed**

### *d) Tolerance*

Hilsenhoff's Biotic Index (HBI) is calculated as a measure of a macroinvertebrate community's tolerance to pollution. HBI scoring is on a scale from zero to ten, with zero indicating unpolluted conditions, thus it is expected that the HBI score will increase from monitoring station 2-NOR003.59 to 2-NOR003.28 and then decrease from monitoring station 2-NOR003.28 to monitoring station 2-NOR000.20, based on the trends of parameters discussed above. At the North Creek monitoring stations, the HBI scores ranged from 5.2 to 7.0 between 1999 and 2001, 4.2 to 5.6 between 2007 and 2008, 4.3 to 5.6 between 2009 and 2010, and 4.0 to 5.4 between 2012 and 2013 (**Figure 3-8).** These data agree with the expected results; HBI scores increased from station 2-NOR003.59 to station 2-NOR003.28 then decreased downstream of the impaired segment at station 2-NOR000.20, indicating the benthic community is recovering downstream from the impairment (**Figure 3-8).**

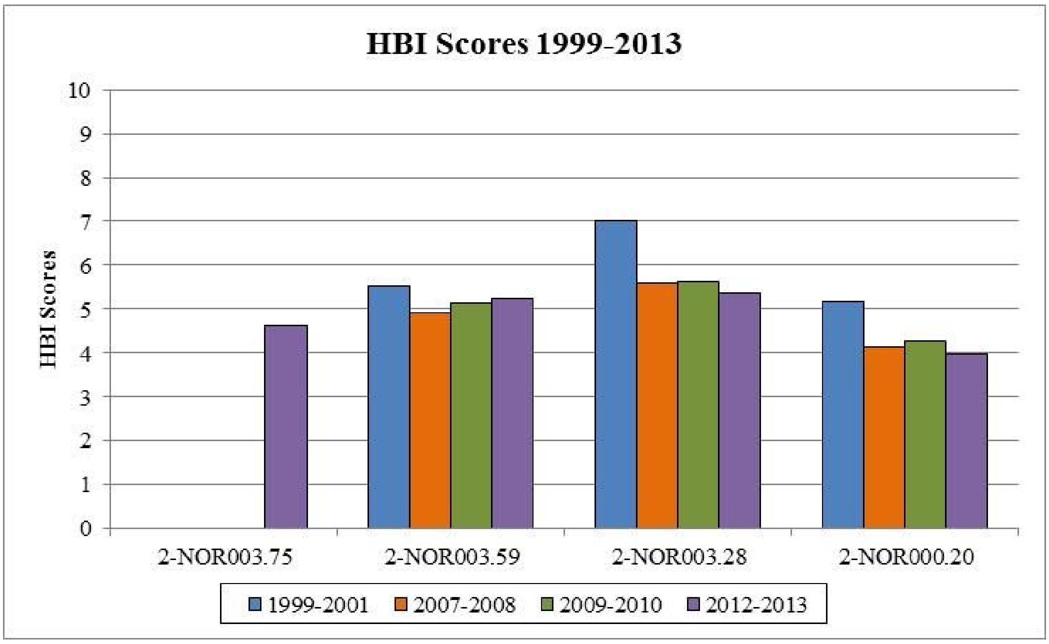



**Figure 3-8: HBI Scores in the North Creek Watershed**

**e)** ***Trophic Group***

Some macroinvertebrates feed by scraping the thin layer of periphyton at the surface of stream substrata. The abundance of scrapers tends to increase with increased diatom and other algal abundance, and decrease as macrophytes, mosses, and blue-green algae accumulate. High levels of sediment, and organic or nutrient pollution causes declines in scraper numbers. Increased sediment loads tend to limit the production of periphyton which, in turn, decreases the available food sources for scrapers. Alternatively, increases in organic or nutrient pollution can cause an accumulation of algae and mosses. At the North Creek monitoring stations the percent composition of scrapers ranged from 2.3 to 15.5 between 1999 and 2001, 3.3 to 7.5 between 2007 and 2008, 4.9 to 7.9 between 2009 and 2010, and 7.7 to 19.5 between 2012 and 2013 (**Figure 3-9**). These data show a decrease in the percent composition of scrapers in a downstream direction, with the overall lowest composition appearing at monitoring station 2-NOR000.20.

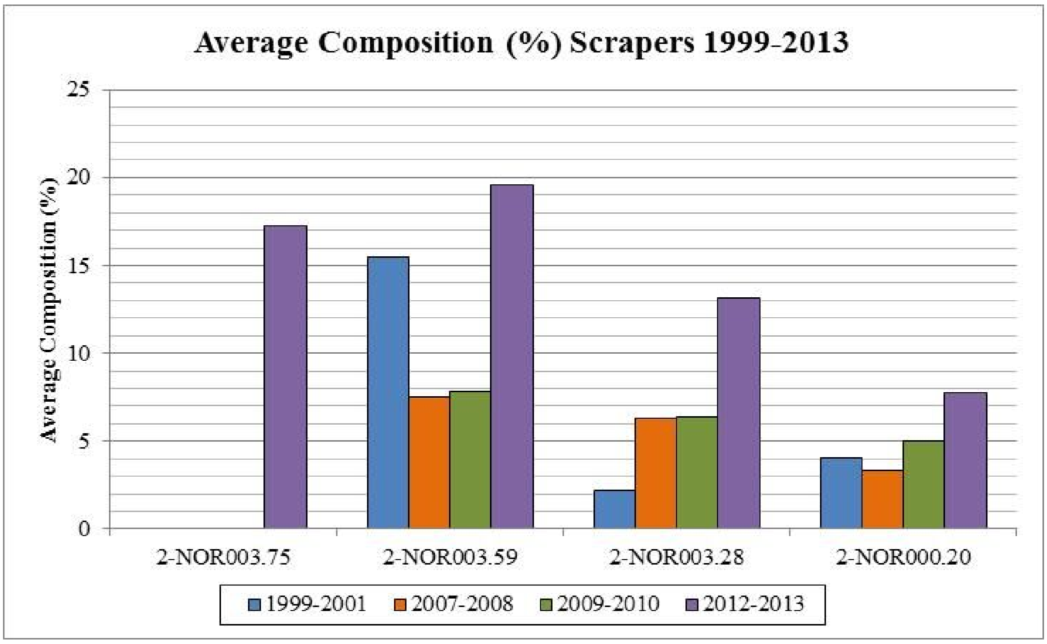



**Figure 3-9: Average Percent Composition of Scrapers in the North Creek Watershed**

### *f) VSCI Results*

The data discussed in the sections above were included by VADEQ in calculating the VSCI scores for the stations 2-NOR003.59, 2-NOR003.28, and 2-NOR000.20. **Table 3-3** shows the VSCI score results for the stations that are discussed in this report.

**Table 3-3: Virginia SCI Scores for North Creek**

| Collection Period | 2-NOR003.75 | 2-NOR003.59 | 2-NOR003.28 | 2-NOR000.20 |
|---|---|---|---|---|
| Spring 1999 | - | 31.0 | 38.4 | - |
| Fall 1999 | - | 48.2 | 32.4 | 35.4 |
| Spring 2000 | - | 47.8 | 30.3 | - |
| Fall 2000 | - | 32.7 | 31.9 | - |
| Fall 2001 | - | 58.0 | 37.7 | - |
| Spring 2007 | - | 56.8 | 31.8 | 71.2 |
| Fall 2007 | - | 53.6 | - | 47.7 |
| Spring 2008 | - | 36.5 | 30.2 | 68.9 |
| Fall 2008 | - | 66.3 | 43.1 | 66.7 |
| Spring 2009 | - | 57.2 | 33.0 | 67.1 |
| Fall 2009 | - | 55.6 | 33.1 | 57.9 |
| Spring 2010 | - | 29.3 | 41.0 | 43.6 |
| Fall 2010 | - | 48.4 | 32.5 | 56.1 |
| Fall 2012 | 66.0 | 65.6 | 51.2 | 74.4 |
| Spring 2013 | 62.9 | 54.2 | 47.8 | 72.2 |

| | | | | |
|---|---|---|---|---|
| **Average 1999-2001** | - | **43.5** | **34.1** | **35.4** |
| **Average 2007-2008** | - | **53.3** | **35.0** | **63.6** |
| **Average 2009-2010** | - | **47.6** | **34.9** | **56.2** |
| **Average 2012-2013** | **64.5** | **59.9** | **49.5** | **73.3** |

During the collection period of 1999 through 2013, VSCI scores met the cutoff score of 60 a total of four times (**Table 3-3**) in the impaired segment of North Creek. Scores were particularly low for station 2-NOR003.28, which is located downstream from the F.U.M.A STP discharger, ranging from 30.2 to 51.2 and averaging 36.7. Station 2-NOR003.75 was added in 2012 to distinguish the benthic community above the confluence of a tributary that Envoy at the Village STP discharges. The two sampling periods for Station 2-NOR003.75 were both above 60, indicating a healthy benthic community. The VSCI scores for the 2007 to 2008 samplings ranged between 30.2 and 71.2 with an average score of 53.3 at station 2-NOR003.59, 35.0 at station 2-NOR003.28, and 63.6 at station 2-NOR000.20. The VSCI scores for the 2009 to 2010 samplings ranged between 29.3 and 67.1 with an average score of 47.6 at station 2-NOR003.59, 34.9 at station 2-NOR003.28, and 56.2 at station 2-NOR000.20. The VSCI scores for the 2012 to 2013 samplings ranged between 47.8 and 74.4 with an average score of 64.5 at station 2-NOR003.75, 59.9 at station 2-NOR003.59, 49.5 at station 2-NOR003.28, and 73.3 at station 2-NOR000.20. The 1999-2001 averages were lowest for the three sets of sampling data; whereas, the 2012-2013 averages were the highest (**Table 3-3**). The composite VSCI data suggest that there is an overall improvement in the health of the benthic community from 1999 to 2013; however, decreases from the 2007-2008 scores to the 2009-2010 scores suggest that a full recovery has not been achieved.

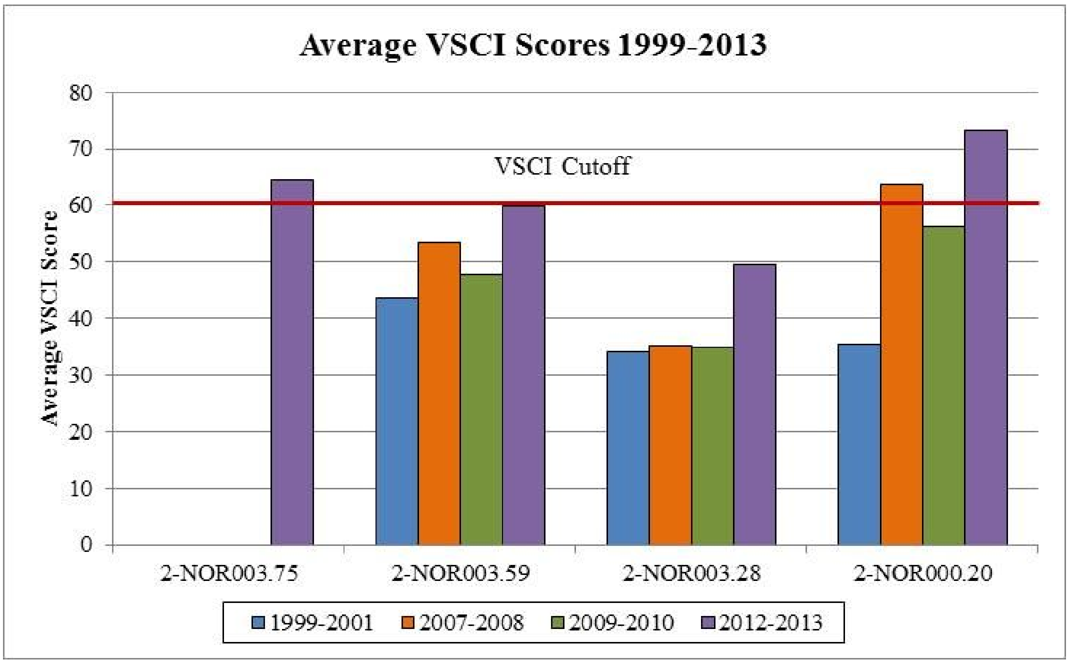



**Figure 3-10: Average VSCI Scores for the North Creek Watershed between 1999 and 2010**

### 3.1.2 Habitat Assessment Scores and Relative Bed Stability

A suite of habitat variables were visually inspected by DEQ at monitoring stations as part of the biological assessments conducted in the North Creek watershed. VA DEQ used EPA's Rapid Bioassessment Protocols (RBP) to qualitatively evaluate the habitat for the benthic community (Barbour et al., 1999). Habitat parameters that were examined include epifaunal substrate, embeddedness, velocity, sedimentation, channel flow, channel alteration, frequency of riffles, bank stability, bank vegetative protection, riparian zone, sinuosity, pool substrate, and pool variability. During each sampling event, parameters were assigned a score from 0 to 20, with 20 indicating optimal conditions, and 0 indicating very poor conditions. VA DEQ assessed habitat scores between 1999 and 2010 for three stations and from 2012 to 2013 for four stations in North Creek. Habitat assessment scores for the biomonitoring stations in the North Creek watershed are presented in **Table 3-4.**

**Table 3-4. North Creek Habitat Scores**

| Station | Sampling Season | Epifaunal Substrate | Embeddedness | Velocity | Sediment Deposition | Channel flow | Channel Alteration | Frequency of Riffles | Bank Stability[1] | Vegetative Protection[1] | Riparian Zone[1] | Sinuosity | Pool Substrate | Pool Variability | Total Habitat Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-NOR003.75 | Fall 2012 | 6 | - | - | 7 | 15 | 13 | - | 4 | 5 | 7 | 13 | 7 | 8 | 85 |
| | Spring 2013 | 10 | - | - | 9 | 16 | 17 | - | 4 | 4 | 10 | 17 | 10 | 11 | 108 |
| | **Avg 2012-2013** | **8** | **-** | **-** | **8** | **16** | **15** | **-** | **4** | **4.5** | **8.5** | **15** | **8.5** | **9.5** | **97** |
| 2-NOR003.59 | Fall 1999 | 13 | 8 | 13 | 8 | 17 | 20 | 11 | 12 | 14 | 15 | - | - | - | 131 |
| | Spring 2000 | 16 | 11 | 10 | 12 | 10 | 17 | 16 | 16 | 16 | 15 | - | - | - | 139 |
| | Fall 2000 | 13 | 10 | 13 | 13 | 18 | 14 | 10 | 16 | 16 | 16 | - | - | - | 139 |
| | Fall 2001 | 3 | 12 | 7 | 6 | 7 | 18 | 5 | 7 | 20 | 5 | - | - | - | 90 |
| | Spring 2007 | 11 | 6 | 16 | 4 | 7 | 18 | 12 | 14 | 16 | 12 | - | - | - | 116 |
| | Fall 2007 | 9 | - | - | 6 | 7 | 12 | - | 8 | 10 | 6 | 12 | 7 | 7 | 84 |
| | Spring 2008 | 13 | 5 | 16 | 5 | 16 | 17 | 13 | 6 | 6 | 14 | - | - | - | 111 |
| | Fall 2008 | 15 | 12 | 16 | 10 | 14 | 16 | 10 | 8 | 8 | 6 | - | - | - | 115 |
| | Spring 2009 | 11 | 11 | 14 | 10 | 16 | 16 | 12 | 10 | 10 | 6 | - | - | - | 116 |
| | Fall 2009 | 9 | - | - | 8 | 10 | 17 | - | 10 | 8 | 4 | 17 | 6 | 16 | 105 |
| | Spring 2010 | 7 | - | - | 7 | 14 | 17 | - | 8 | 8 | 4 | 14 | 8 | 10 | 97 |
| | Fall 2010 | 7 | - | - | 8 | 6 | 16 | - | 10 | 10 | 4 | 15 | 10 | 10 | 96 |
| | Fall 2012 | 14 | - | - | 10 | 15 | 16 | - | 8 | 8 | 6 | 16 | 10 | 16 | 119 |
| | Spring 2013 | 12 | - | - | 10 | 17 | 16 | - | 6 | 6 | 4 | 16 | 10 | 16 | 113 |
| | **Avg 2007-2013** | **11** | **9** | **15** | **8** | **13** | **16** | **12** | **8** | **8** | **6** | **15** | **9** | **13** | **106** |
| 2-NOR003.28 | Fall 1999 | 16 | 14 | 15 | 11 | 18 | 20 | 17 | 16 | 18 | 20 | - | - | - | 165 |
| | Spring 2000 | 16 | 11 | 15 | 12 | 13 | 18 | 11 | 18 | 18 | 19 | - | - | - | 151 |
| | Fall 2000 | 13 | 13 | 16 | 16 | 18 | 19 | 8 | 20 | 20 | 20 | - | - | - | 163 |
| | Fall 2001 | 10 | 12 | 13 | 5 | 9 | 18 | 12 | 14 | 20 | 20 | - | - | - | 133 |
| | Spring 2007 | 16 | 11 | 8 | 12 | 10 | 14 | 16 | 18 | 18 | 20 | - | - | - | 143 |
| | Spring 2008 | 10 | 10 | 16 | 10 | 16 | 16 | 16 | 4 | 4 | 20 | - | - | - | 122 |
| | Fall 2008 | 16 | 14 | 16 | 13 | 13 | 16 | 16 | 15 | 15 | 18 | - | - | - | 152 |
| | Spring 2009 | 11 | 10 | 16 | 10 | 16 | 14 | 15 | 14 | 14 | 14 | - | - | - | 134 |
| | Fall 2009 | 12 | 10 | 17 | 10 | 12 | 16 | 18 | 16 | 14 | 18 | - | - | - | 143 |
| | Spring 2010 | 11 | - | - | 8 | 13 | 17 | - | 16 | 16 | 16 | 11 | 9 | 16 | 133 |
| | Fall 2010 | 11 | 6 | 16 | 8 | 12 | 16 | 17 | 10 | 10 | 16 | - | - | - | 122 |
| | Fall 2012 | 14 | 10 | 15 | 9 | 15 | 15 | 17 | 12 | 14 | 16 | - | - | - | 137 |
| | Spring 2013 | 16 | 10 | 15 | 10 | 18 | 17 | 18 | 16 | 16 | 13 | - | - | - | 149 |
| | **Avg 2007-2013** | **13** | **10** | **15** | **10** | **14** | **16** | **17** | **13** | **13** | **17** | **11** | **9** | **16** | **137** |

**Table 3-4. North Creek Habitat Scores**

| Station | Sampling Season | Epifaunal Substrate | Embeddedness | Velocity | Sediment Deposition | Channel flow | Channel Alteration | Frequency of Riffles | Bank Stability[1] | Vegetative Protection[1] | Riparian Zone[1] | Sinuosity | Pool Substrate | Pool Variability | Total Habitat Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-NOR000.20 | Fall 1999 | 14 | 15 | 10 | 10 | 18 | 18 | 16 | 8 | 9 | 19 | - | - | - | 137 |
| | Spring 2007 | 6 | - | - | 5 | 7 | 18 | - | 12 | 16 | 11 | 13 | 6 | 6 | 100 |
| | Fall 2007 | 6 | - | - | 4 | 8 | 14 | - | 4 | 4 | 16 | 11 | 6 | 7 | 80 |
| | Spring 2008 | 11 | - | - | 6 | 16 | 16 | - | 4 | 4 | 19 | 12 | 6 | 8 | 102 |
| | Fall 2008 | 13 | - | - | 7 | 13 | 15 | - | 9 | 9 | 14 | 15 | 7 | 7 | 109 |
| | Spring 2009 | 10 | - | - | 7 | 15 | 15 | - | 8 | 8 | 17 | 14 | 8 | 8 | 110 |
| | Fall 2009 | 10 | - | - | | 7 | 15 | - | 10 | 10 | 17 | 15 | 11 | 8 | 103 |
| | Spring 2010 | 11 | - | - | 7 | 16 | 16 | - | 6 | 6 | 16 | 14 | 8 | 9 | 109 |
| | Fall 2010 | 8 | - | - | 6 | 7 | 16 | - | 10 | 10 | 13 | 14 | 8 | 9 | 101 |
| | Fall 2012 | 13 | - | - | 8 | 10 | 16 | - | 8 | 8 | 13 | 15 | 10 | 10 | 111 |
| | Spring 2013 | 15 | - | - | 7 | 17 | 16 | - | 8 | 6 | 12 | 16 | 7 | 16 | 120 |
| | **Avg 2007-2013** | **10** | **N/A** | **N/A** | **6** | **12** | **16** | **N/A** | **8** | **8** | **15** | **14** | **8** | **9** | **105** |

[1]The total score is presented here. The left and right banks are scored separately.

Overall, the average total habitat assessment scores increased from station 2-NOR003.75 to 2-NOR003.28 and then decreased from 2-NOR003.28 to 2-NOR000.20. The habitat assessment scores from 2007-2013 were generally low at all stations in the North Creek watershed with scores ranging between 80 and 152 with an average score of 114. Scores for habitat metrics such as epifaunal substrate, embeddedness, sediment deposition, and bank stability, were consistently low for the stations on the impaired segment of North Creek. The following is a summary of the seven habitat metrics that scored low for the whole watershed:

- The epifaunal substrate metric is a measure of the relative quantity and variety of natural structures in the stream for spawning and nursery functions of aquatic macrofauna. In the North Creek watershed, scores from the 2007 to 2013 samplings ranged between 6 and 16 with an average score of 11. Earlier samplings also yielded similar scores, but averaged 13, indicating slight degradation over time to the overall habitat in North Creek.

- The embeddedness metric is the extent to which rocks and snags are covered or sunken in silt, sand, or mud in the stream bottom. In the North Creek watershed, scores from the 2007-2013 samplings ranged between 5 and 14 with an average score of 10. Scores from earlier samplings were slightly higher, ranging between 8 and 15 with an average of 12. All of the habitat scores, including embeddedness, describe optimal conditions at the higher end of the scale and degraded conditions at the lower end. Although somewhat counterintuitive, a high embeddedness score indicates little to no silt or sand covering the rocks and snags, while a low embeddedness score indicates a greater quantity of silt or sand covering the rocks and snags. Therefore, going from a higher average score (12) in earlier samplings to a lower average score (10) in 2007-2013 indicates slight degradation over time to the overall habitat in North Creek .

- The sediment deposition metric is the amount of sediment that has accumulated in pools and the changes that have occurred to the stream's bars or islands due to deposition. Lower scores would indicate large-scale movement of sediment is occurring in the stream. Sediment deposition scores from the 2007-2013 samplings ranged from 4 to 13 with an average of 8. Earlier samplings yielded similar scores with a range between 5 and 16 and an average score of 10.

- The bank stability metric is the measure of whether stream banks have eroded or have the potential for erosion. Scores from the 2007-2013 samplings ranged between 4 and 18 with an average of 10. Earlier samplings at 2-NOR003.59 and 2-NOR003.28 had slightly higher scores with a range between 7 and 20 and an average score of 14, indicating erosion is increasing over time. The 2012-2013 scores show high levels of erosion at all stations besides 2-NOR003.28.

- The vegetative protection metric is the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. This parameter provides insight on the ability of the bank to resist erosion as well as instream shading, plant nutrient uptake and control of instream scouring. Vegetative protection scores from the 2007-2013 samplings ranged from 4 to 18 with an average of 10. Earlier samplings ranged from 9 to 20 and averaged 17, indicating a significant decline in the vegetative protection and contributing to the increase in erosion of the banks of North Creek over the monitoring period.

- Pool substrate is a measure of the bottom substrates found in pools. A stream that supports a variety of substrates in its pools will support a more diverse benthic community. Pool variability is a measure of the mixture of pool types found in the streams according to size and depth. A larger variety of streams will also support a more diverse benthic community. The 2007 – 2013 pool substrate scores ranged from 6 to 11 with an average score of 8 and pool variability scores ranged from 6 to 16 with an average of 10, indicating marginal pool substrate and variability within North Creek.

The following are the notes listed in VA DEQ's 2010 Integrated 305(b)/303(d) Assessment:

- Station 2-NOR003.59 (2007-2008) –This stream has unstable banks, a high rate of sediment deposition, and substrate covered with abundant filamentous algae. The samples collected in the fall of 2008 showed improved conditions. Monitoring at this site is ongoing.

- Station 2-NOR003.28 (2007-2008) – This site is characterized by bedrock and cobble riffles that are embedded with sediment, and algae covers most of the substrate. Monitoring at this site is ongoing.

In **Table 3-5** are notes taken by DEQ biologists during the habitat assessment.

**Table 3-5: Habitat Assessment Notes for North Creek**

| Sampling Season | Station | Notes | Total Habitat Score |
|---|---|---|---|
| Spring 2007 | 2-NOR003.59 | Some bedrock, lots of sand. | 116 |
| | 2-NOR003.28 | Some bedrock, looks like granite. Plenty of cobble but sediment deposition occurring. Low incised height. | 143 |

| Table 3-5: Habitat Assessment Notes for North Creek | | | |
|---|---|---|---|
| **Sampling Season** | **Station** | **Notes** | **Total Habitat Score** |
| | 2-NOR000.20 | LWD and snags most productive. No riffles available (sandy stream). Very sandy, many bars, banks w/few scars; loose sediments instream; majority of stream a shallow run; very little pools or habitat variability. | 100 |
| Spring 2008 | 2-NOR003.59 | Bedrock common. Fields on both banks beyond riparian zone. Filamentous algae almost as prevalent as site below STP. | 111 |
| | 2-NOR003.28 | Half of riffles good, half gravelly and not as good. Filamentous algae covering sandy stream bottom. | 122 |
| | 2-NOR000.20 | Major sedimentation, unstable banks. Plenty of leaf packs. | 102 |
| Fall 2009 | 2-NOR000.20 | Flow very low | 103 |
| Spring 2010 | 2-NOR003.59 | Field/riparian area being developed on Left Bank | 97 |
| Fall 2010 | 2-NOR003.59 | Was almost completely dry two months ago. Algae on everything. | 96 |
| | 2-NOR000.20 | Stream was dry in September | 101 |

**Relative Bed Stability**

Relative Bed Stability (RBS) is a quantitative measure of “stream power” or relative bed particle mobility. A Log Relative Bed Stability (LRBS) near 0 indicates the stream is stable (Kaufmann *et al.*, July 1999, Oct. 2007). Results of an August 2009 RBS data collection indicates that North Creek is more stable (closer to 0) at the upstream sites (2-NOR003.59 and 2-NOR003.28) than at the site downstream (2-NOR000.20). **Table 3-6** shows the results of the Relative Bed Stability study.

| Table 3-6: Relative Bed Stability Results (presented in last column as log Relative Bed Stability). | | |
|---|---|---|
| Station ID | Station Location | LRBS |
| 2-NOR003.59 | Upstream of F.U.M.A STP Discharge | -0.278890 |
| 2-NOR003.28 | Downstream of F.U.M.A STP Discharge | -0.238493 |
| 2-NOR000.20 | Rt. 654 bridge | -1.169821 |

### 3.1.3 Ambient Water Quality Monitoring

Water quality monitoring stations located along the benthic impaired segment and downstream of the segment were used in the development of this TMDL. This includes stations 2-NOR003.75, 2-NOR003.59, and 2-NOR003.28 within the benthic impaired segment, 2-NOR000.20 downstream of the impaired segment, and point source monitoring at stations VA0024147 and VA0081639-001. **Table 3-7** shows the water quality monitoring stations used in the TMDL, the available date range, and maximum number of samples (Count).

**Table 3-7: North Creek Monitoring Station Summary**

| Stream | Station | Description | Sampling Dates | | Count |
|---|---|---|---|---|---|
| | | | Start | End | |
| **Impaired** | 2-NOR003.75 | North Creek Upstream of UT NC Confluence | 2/29/2012 | 5/29/2013 | 14 |
| | 2-NOR003.59 | Upstream of F.U.M.A Discharge | 6/22/2000 | 5/29/2013 | 28 |
| | 2-NOR003.28 | Below F.U.M.A. STP Discharge | 6/22/2000 | 5/29/2013 | 29 |
| **Non-Impaired** | 2-NOR000.20 | Rt. 654 bridge | 7/11/2005 | 5/29/2013 | 27 |
| **Point Source Monitoring** | VA0024147 | F.U.M.A. STP | 6/6/2012 | 8/7/2012 | 6 |
| | VA0081639-001 | The Village Nursing Center | 9/4/2003 | 5/29/2013 | 14 |

VA DEQ collected instream water quality samples at these stations. The instream water quality measurements included general parameters (temperature, DO, pH, and spec. conductivity) and chemical parameters (nutrients, solids). For the analysis, only data collected from 2000-2013 were analyzed and compared to VA DEQ water quality standards.

#### 3.1.3.1. Ambient Water Quality Monitoring Summary

A summary of selected instream data within North Creek is given below. The summary also includes figures of the selected instream data (For some parameters, $BOD_5$, TSS, Total $NH_3$-N, and $PO_4$-P, the detection limits often create a horizontal straight line of low values in the figures).

- Field dissolved oxygen data, presented in **Figure 3-11,** indicated that the majority of the time, adequate DO levels are found in the benthic impaired segment of the North Creek (range: 4.4–13.9 mg/L). There are no exceedances of the 4.0 mg/L minimum standard.

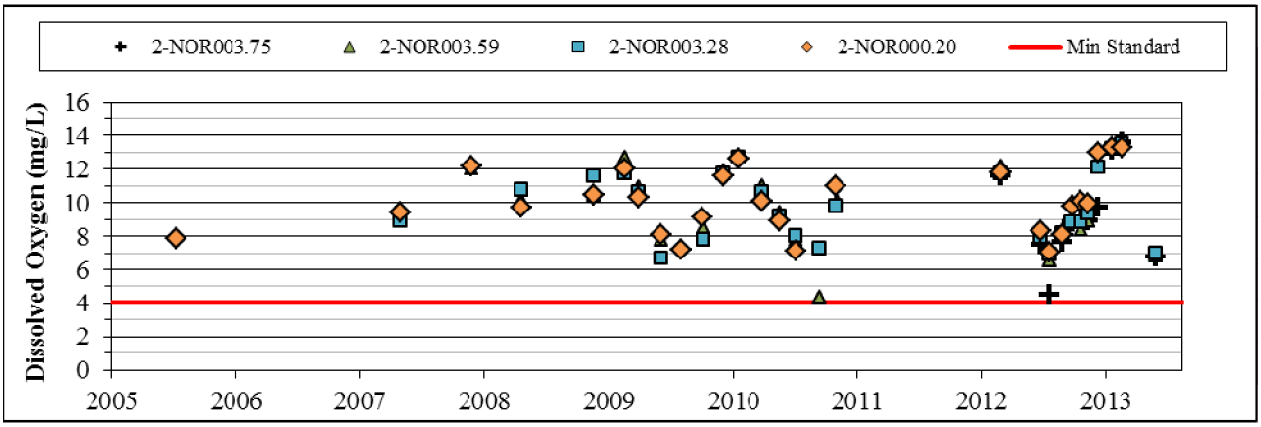



**Figure 3-11: Ambient Dissolved Oxygen Measurements in North Creek**

- The pH values did not meet VA DEQ's water quality standard of maintaining pH levels in between 6 to 9 twice; once at 5.9 and another at 9.4, but the majority of samples were in the acceptable pH range. (**Figure 3-12**)

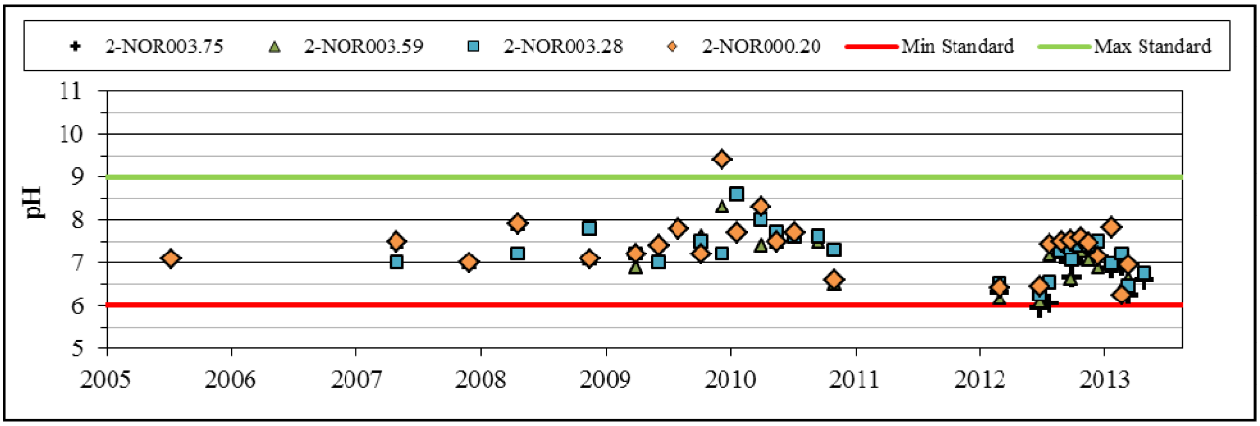



**Figure 3-12: Ambient pH Measurements in North Creek**

- All temperature (range: 1.8-26.3°C) values did not exceed VA DEQ criterion of a maximum of 32° Celsius (**Figure 3-13**).

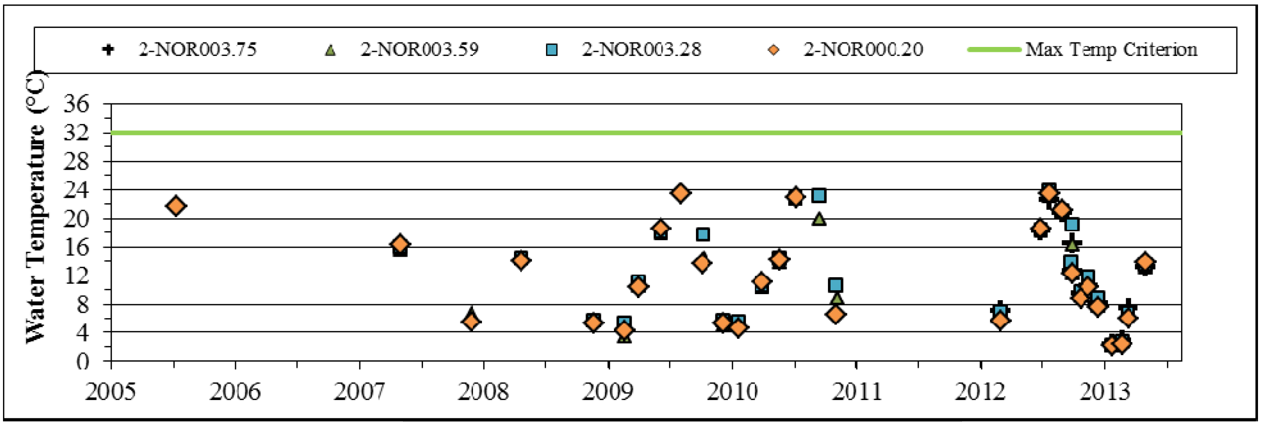



**Figure 3-13: Ambient Temperature Measurements in North Creek**

- Specific Conductivity levels were on average approximately 157.2 µmhos/cm and ranged between 55 and 826 µmhos/cm (**Figure 3-14**). The VA DEQ "reference-filter" value for Specific Conductance in the Piedmont Ecoregion, established at < 250 µmhos/cm (VA DEQ 2006b), was exceeded four times.

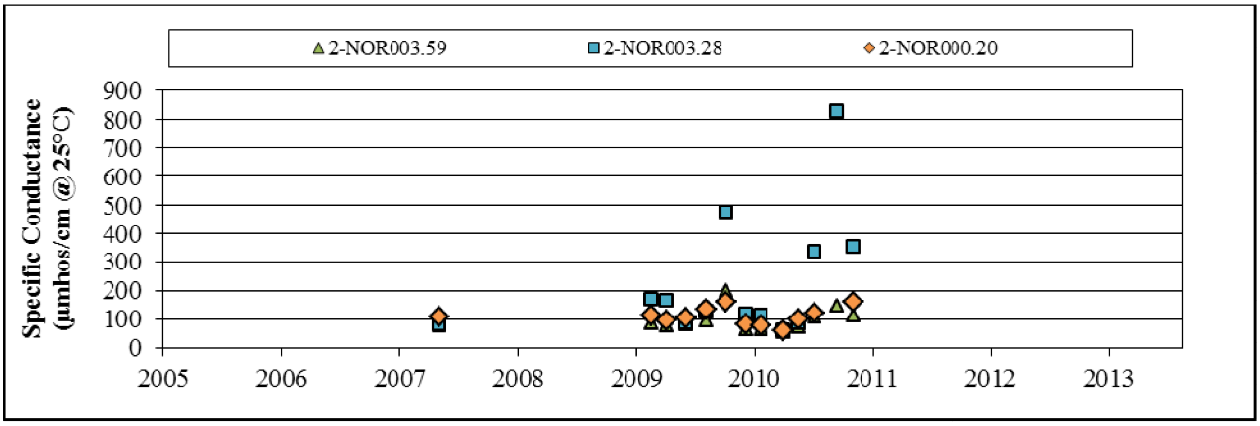



**Figure 3-14: Ambient Specific Conductivity Measurements in North Creek**

- Biochemical oxygen demand ($BOD_5$) concentrations ranged between 1.5 and 5 mg/L, with an average of 2.17 mg/L (**Figure 3-15**). The detection limit for BOD is 1 mg/L. There are no screening values for BOD established by the VA DEQ.

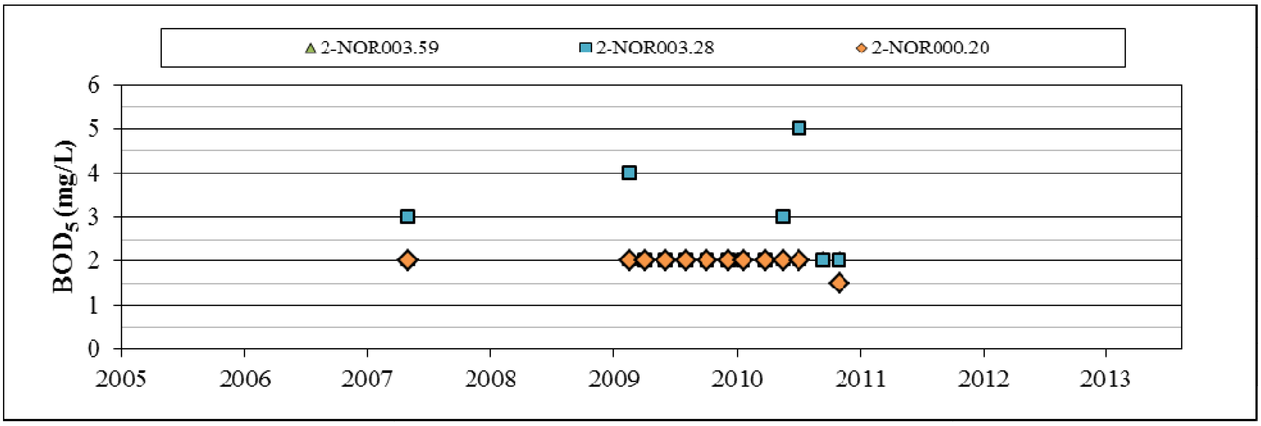



**Figure 3-15: Ambient $BOD_5$ Measurements in North Creek**

- Total suspended solids (TSS, total non-filterable residue) concentrations ranged between 3 and 70 mg/L (**Figure 3-16**). The minimum detection limit for TSS is 3 mg/L. There are no VA DEQ screening values for TSS levels.

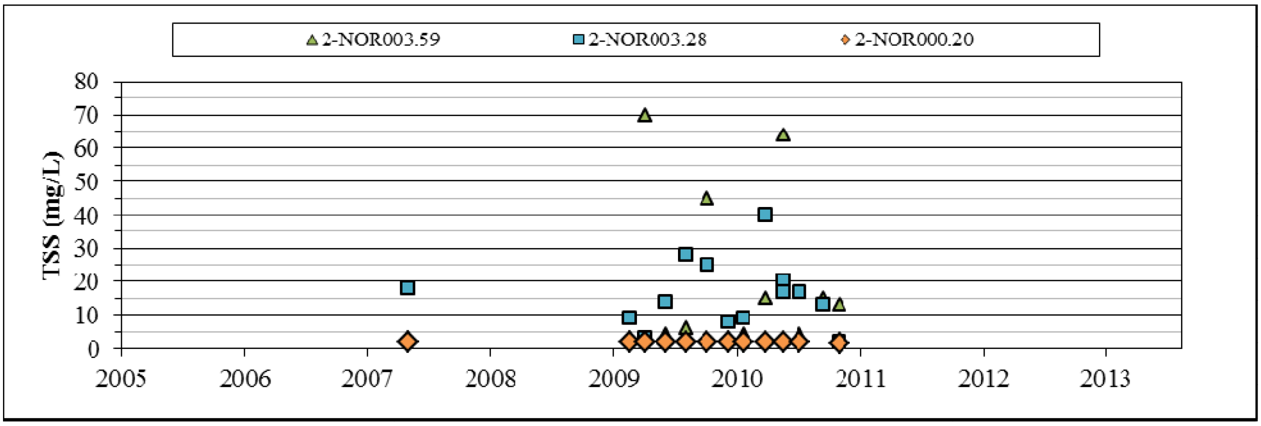



**Figure 3-16: Ambient TSS Measurements in North Creek**

- On average, turbidity levels ranged between 1.54 and 43.2 Nephelometric Turbidity Units (NTU) (**Figure 3-17**).

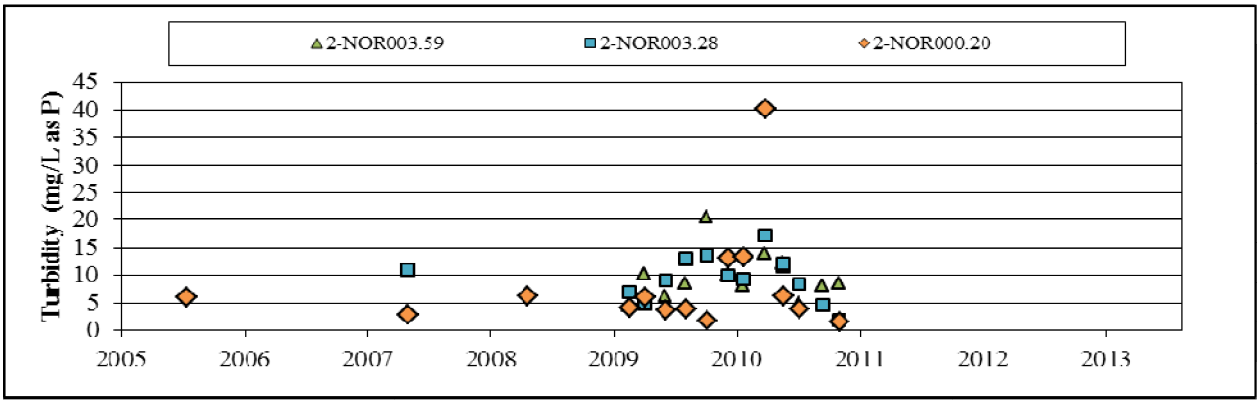



**Figure 3-17: Ambient Turbidity Measurements in North Creek**

- Total ammonia concentrations did not exceed VA DEQ total ammonia criteria for freshwater when trout are absent. VA DEQ ammonia criteria vary with pH, water temperature, and the presence of sensitive fish (trout). They ranged between 0.04 and 0.64 mg/L (**Figure 3-18**). The detection limit for ammonia is 0.04 mg/L.

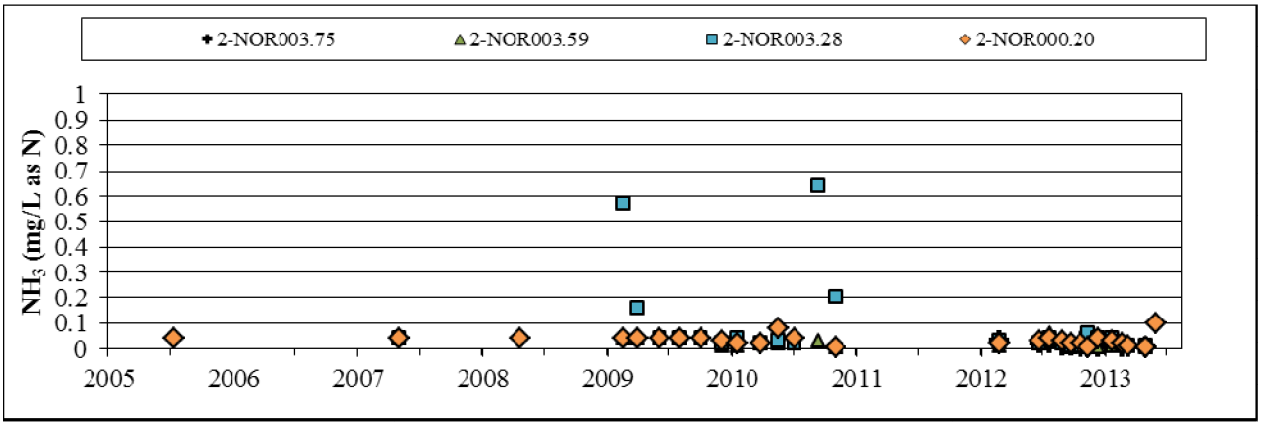



**Figure 3-18: Ambient Total Ammonia Measurements in North Creek**

- $NO_3$-N (Nitrate) concentrations ranged from 0.01 to 31 mg/L. $NO_2$-N (Nitrite) concentrations ranged between and 0.004 and 0.09 mg/L for $NO_2$-N (**Figure 3-19 and 3-20**). There were particularly high nitrate and nitrite concentrations from station 2-NOR003.28. . It should be noted that the most downstream station (2-NOR000.20) appears to have assimilated the high levels of nitrate and nitrites measured at station 2-NOR003.28.

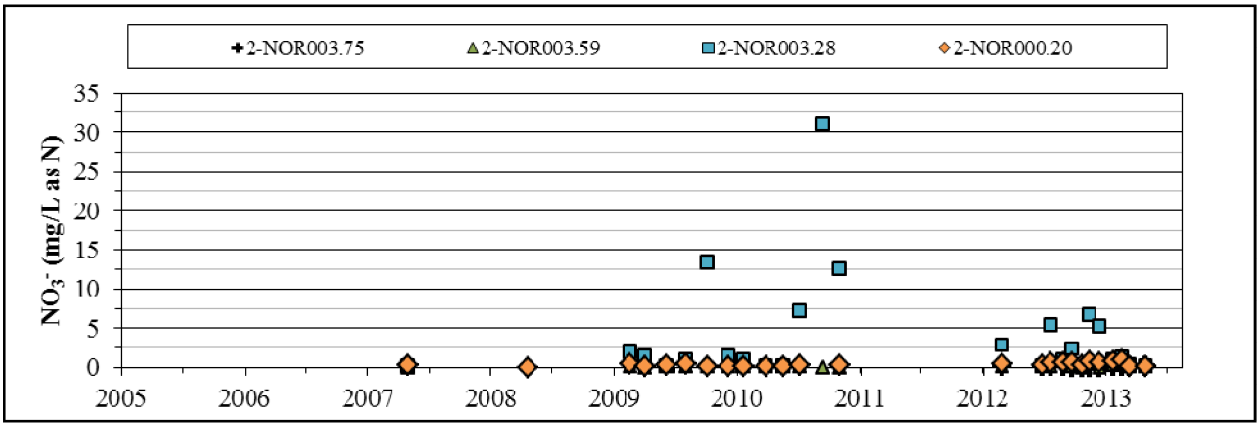



**Figure 3-19: Ambient Nitrate Measurements in North Creek**

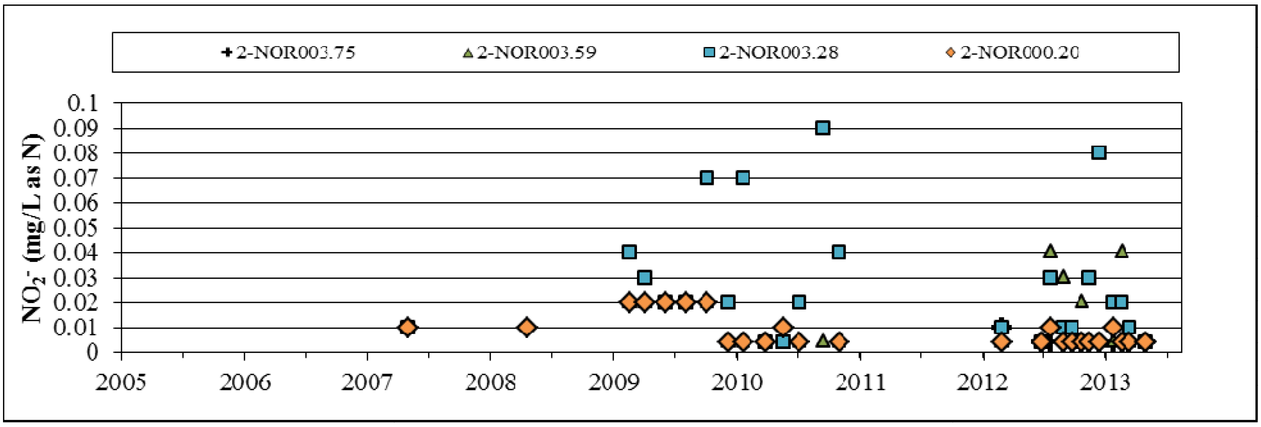



**Figure 3-20: Ambient Nitrite Measurements in North Creek**

- Total Kjeldahl Nitrogen (TKN) concentrations ranged between 0.2 and 2.0 mg/L (**Figure 3-21**). There are no DEQ screening values for total kjeldahl nitrogen.

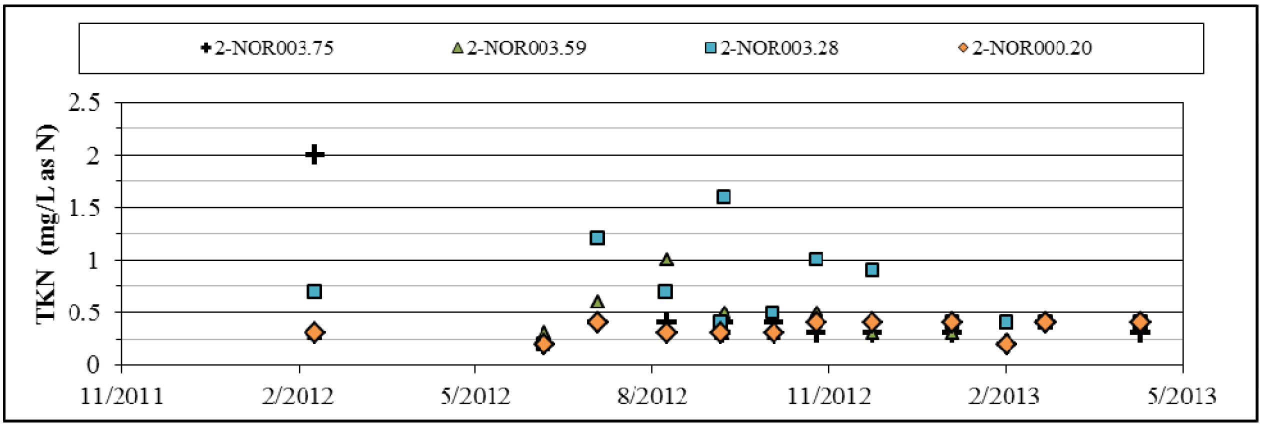



**Figure 3-21: Ambient Total Kjeldahl Nitrogen Measurements in North Creek**

- Total Nitrogen (TN) concentrations ranged between 0.14 and 7.18 mg/L (**Figure 3-22**). There are no DEQ screening values for total nitrogen but values were highest at the monitoring station 2-NOR003.28. . It should be noted that the most downstream station (2-NOR000.20) appears to have assimilated the high levels of nitrogen measured at station 2-NOR003.28.

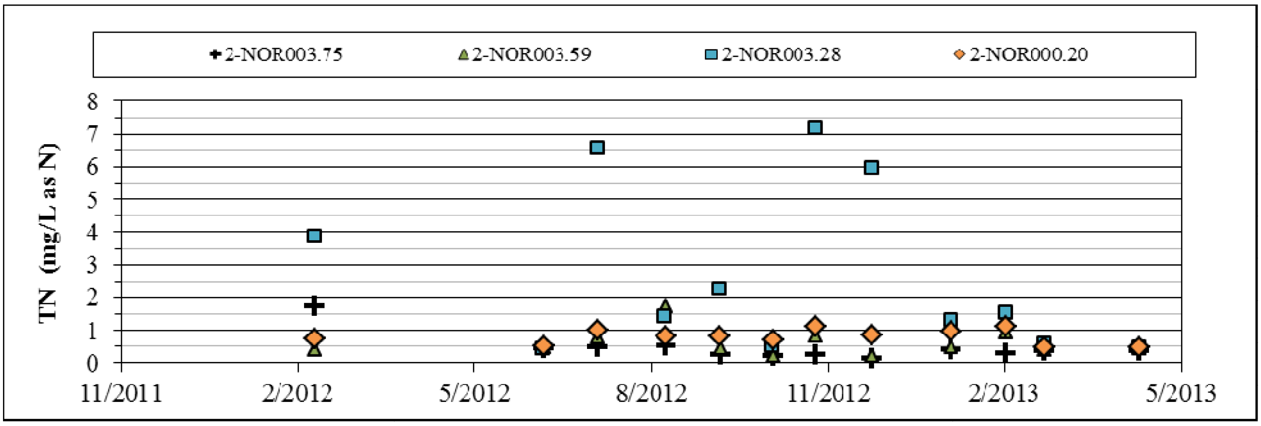



**Figure 3-22: Ambient Total Nitrogen Measurements in North Creek**

- Ortho-phosphorus ($PO_4$-P) concentrations ranged between 0.01 and 9.9 mg/L (**Figure 3-23**). There are no DEQ screening values for ortho-phosphorous. The minimum detection limit for ortho-phosphorous is 0.01 mg/L. Concentrations of ortho-phosphorus were highest at station 2-NOR003.28. It should be noted that the most downstream station (2-NOR000.20) appears to have assimilated the high levels of phosphorus measured at station 2-NOR003.28.

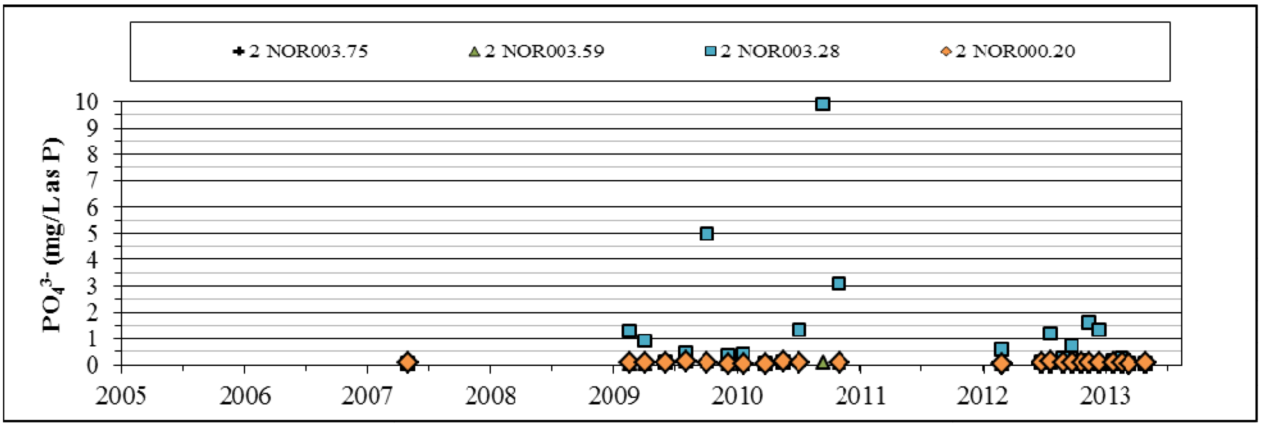



**Figure 3-23: Ambient Ortho-Phosphorus Measurements in North Creek**

- Total Phosphorus (TP) concentrations ranged between 0.02 and 3.92 mg/L (**Figure 3-24**). TP concentrations were highest from station 2-NOR003.28. It should be noted that the most downstream station (2-NOR000.20) appears to have assimilated the high levels of phosphorus measured at station 2-NOR003.28.

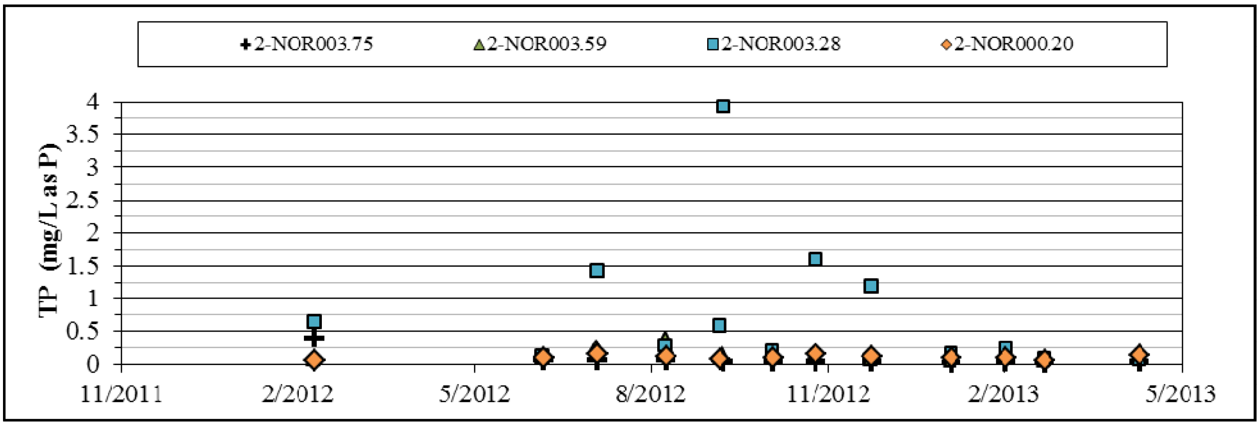



**Figure 3-24: Ambient Total Phosphorus Measurements in North Creek**

#### 3.1.3.2. Metal Data

Dissolved metal parameters were measured at monitoring station 2-NOR003.28. Metals measured included aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc. All available dissolved metal data were analyzed to determine whether the examined parameters complied with Virginia's established water quality standards. No monitored metals parameters exceeded the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards for dissolved metals.

Additionally, although there are currently no water quality standards established for metals in sediment, the Fish Tissue and Sediment Toxics Evaluation memorandum (VA DEQ, 2008) establishes consensus based Effective Range – Medium (ER-M) for use in determining aquatic life use support. Metals in sediment collected at monitoring station 2-NOR003.28 were analyzed to determine whether they complied with the consensus based screening values. Metals measured included aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc. Though many compounds were noted in sediment testing, none exceeded the thresholds for the ER-M.

### 3.1.4 Continuous Measurement of Field Parameters Under Dry Weather Conditions

VA DEQ conducted continuous instream measurements for temperature and dissolved oxygen at three stations from August 4th to August 6th, 2009 in the North Creek watershed (**Table 3-8**).

**Table 3-8: Monitoring Sites and Period of Measurements for Continuous Measurements in the North Creek Watershed**

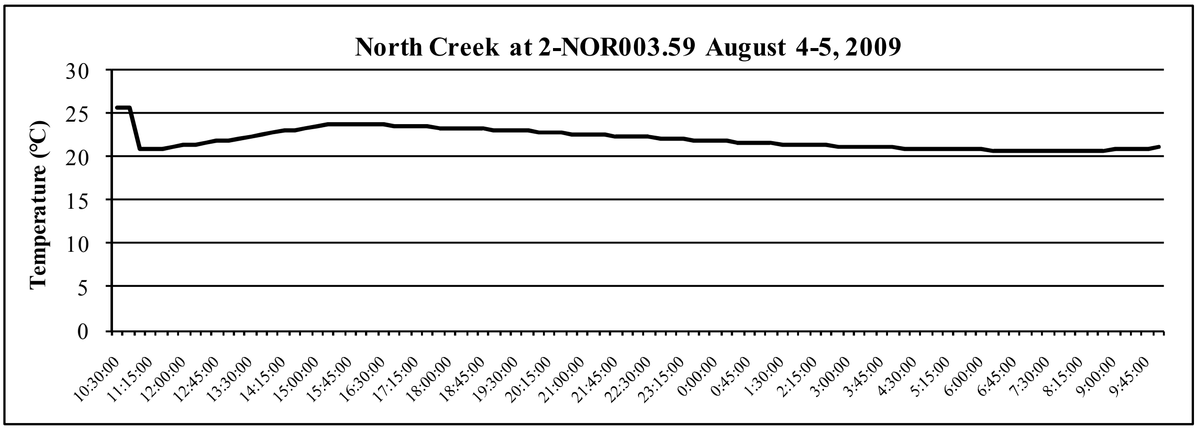
| Monitoring Station | Period of Measurements |
|---|---|
| 2-NOR003.59 | August 4th -5th, 2009 |
| 2-NOR003.28 | August 4th -6th, 2009 |
| 2-NOR000.20 | August 5th -6th, 2009 |

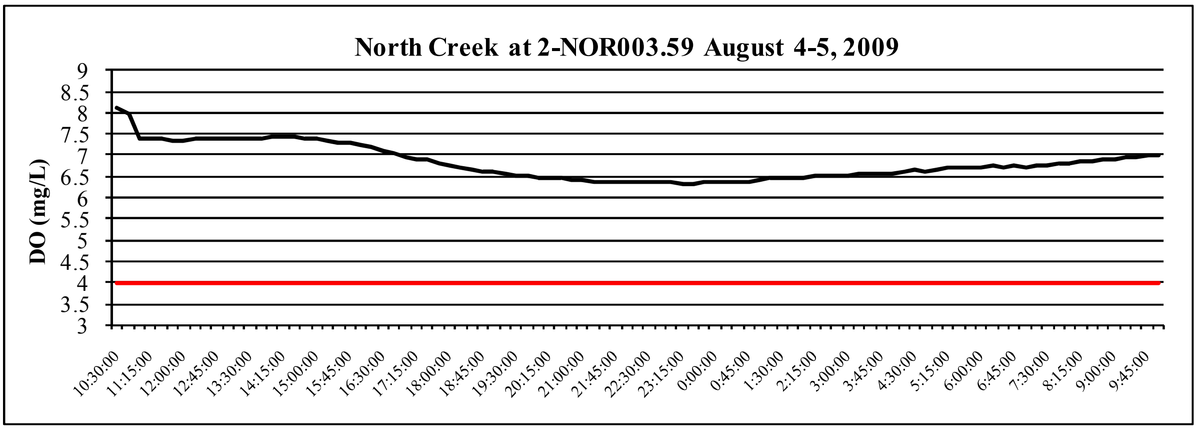
Overall, the continuous measurements showed relatively small fluctuations and there were no exceedances of VA DEQ criteria for temperature or dissolved oxygen. **Table 3-9** and **Figures 3-25** through **3-27** show the results of the continuous measurements conducted during the growing season at three stations located within the benthic impaired segment and one downstream of the impaired segment.

**Table 3-9: Summary of Instream Continuous Measurements Over Two Days in North Creek**

| 2-NOR003.59 | | | | 2-NOR003.28 | | | 2-NOR000.20 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Temp | DO | DO | Temp | DO | DO | Temp | DO | DO |
| | C | % | mg/L | C | % | mg/L | C | % | mg/L |
| COUNT | 95 | 95 | 95 | 197 | 197 | 197 | 87 | 86 | 86 |
| AVG | 22.0 | 78.1 | 6.8 | 22.6 | 83.4 | 7.2 | 22.6 | 81.6 | 7.0 |
| MIN | 20.7 | 72.4 | 6.3 | 21.1 | 77.0 | 6.6 | 21.5 | 77.9 | 6.7 |
| MAX | 25.8 | 99.8 | 8.1 | 24.9 | 100.8 | 8.4 | 24.1 | 84.6 | 7.3 |
| Swing (mg/L)[1] | 5.1 | 27.4 | 1.8 | 3.9 | 21.8 | 1.6 | 2.6 | 6.7 | 0.6 |

[1]Difference over 24 hours between 10:30 AM at day 1 and 10:30 AM at day 2



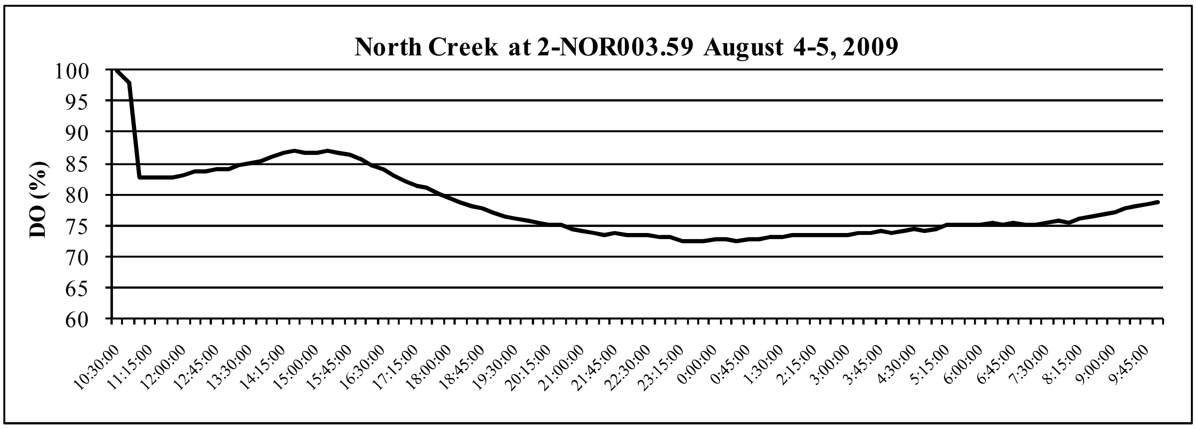




**Figure 3-25: Continuous Measurements for Temperature and DO at Monitoring Station 2-NOR003.59 August 4th - 5th, 2009**

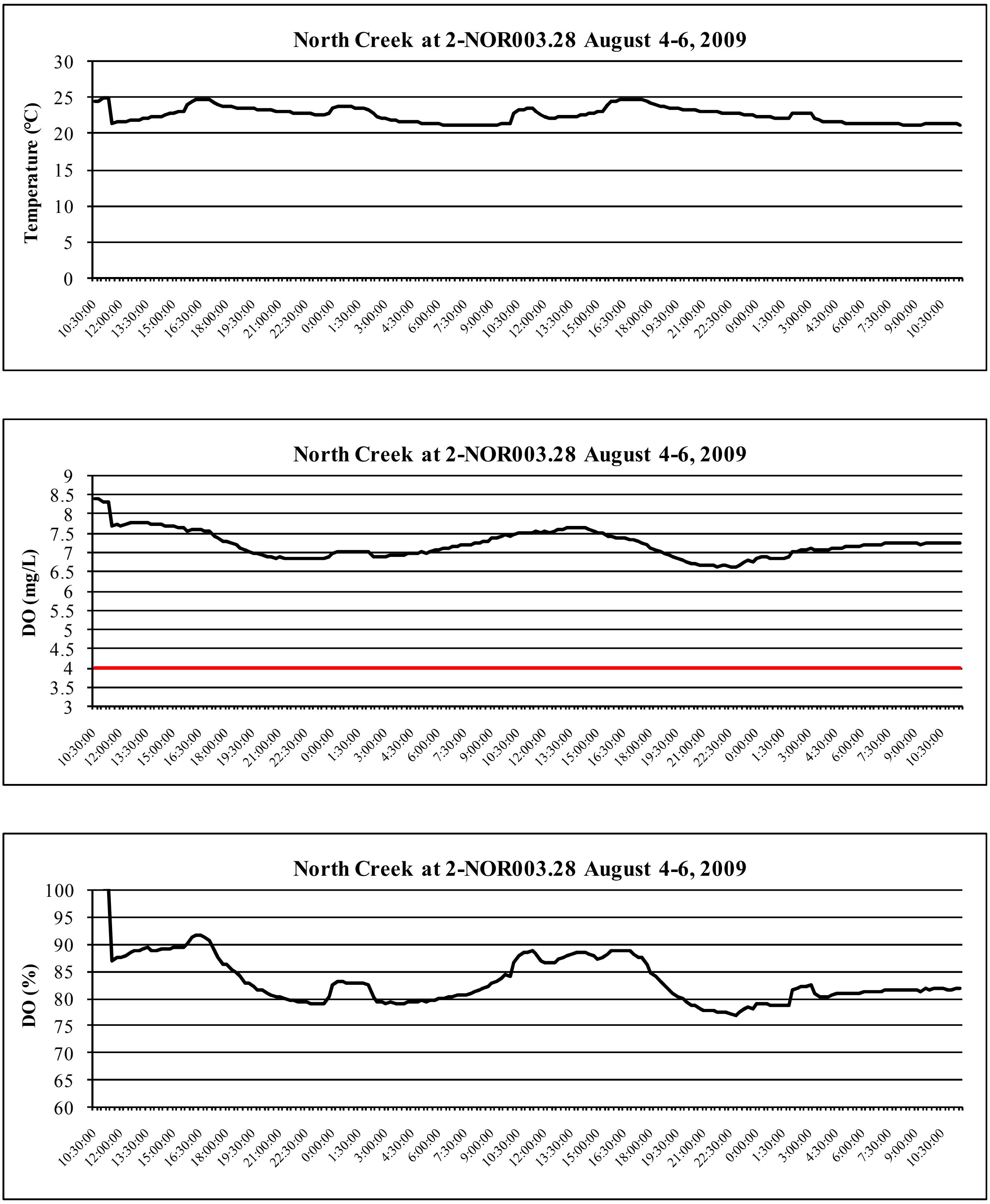
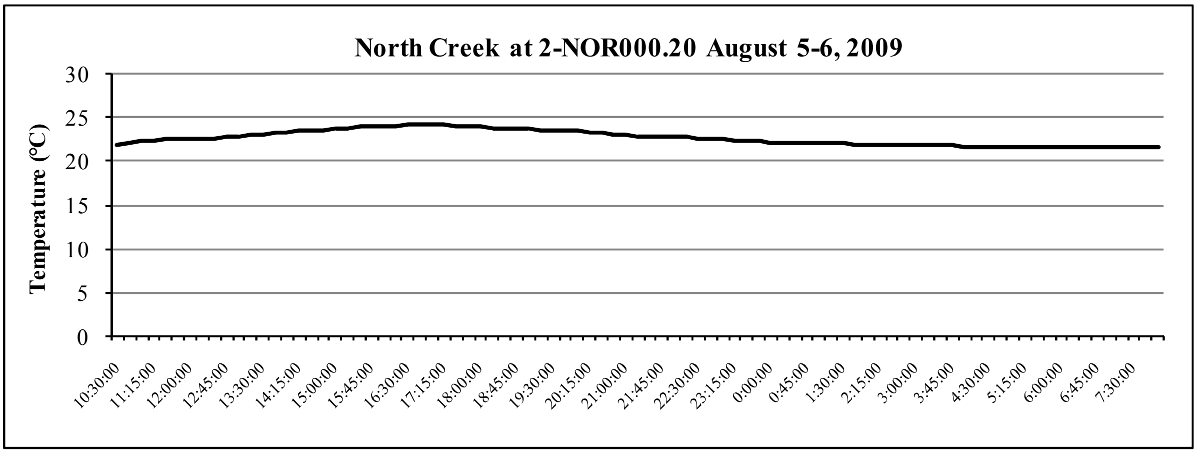
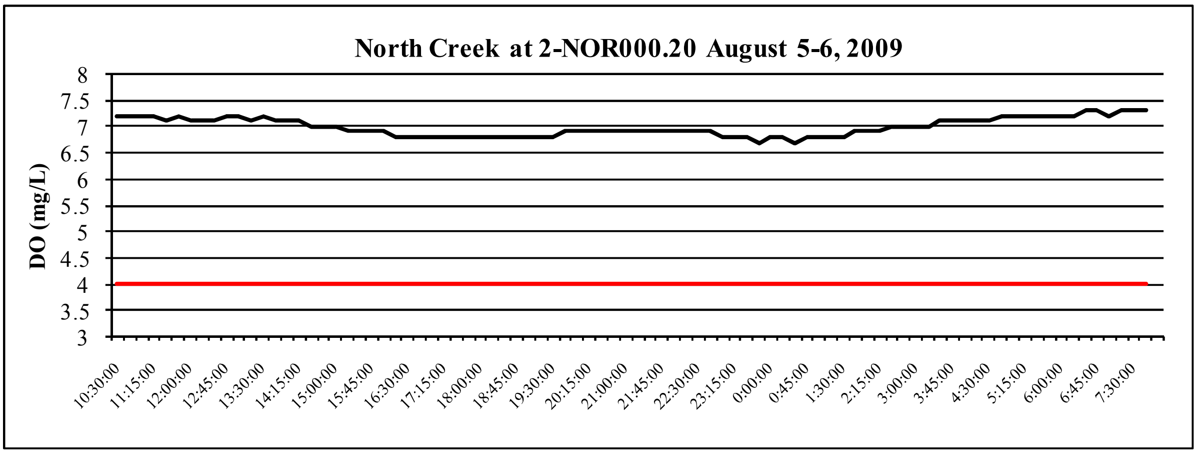



**Figure 3-26: Continuous Measurements for Temperature and DO at Monitoring Station 2-NOR003.28 August 4$^{th}$ - 6$^{th}$, 2009**



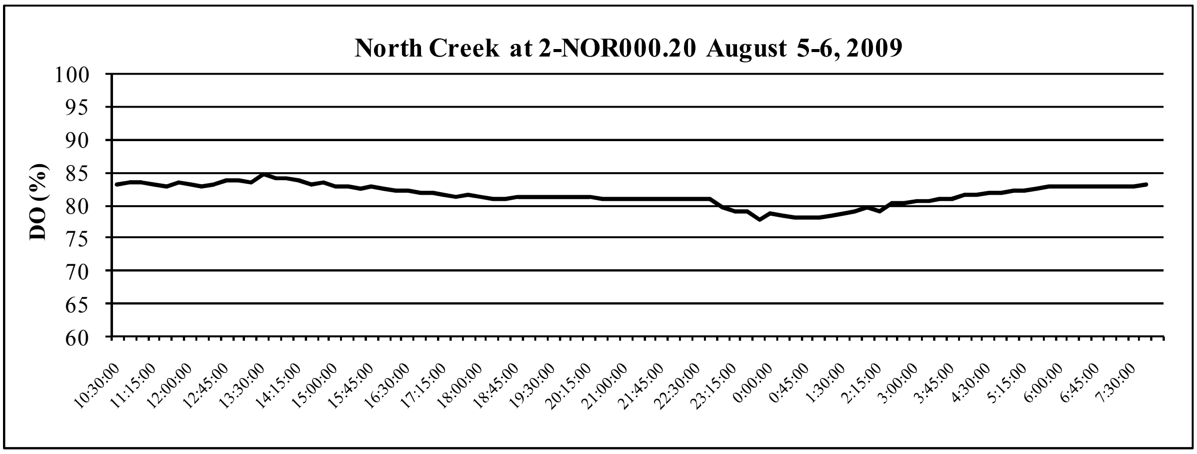




**Figure 3-27: Continuous Measurements for Temperature and DO at Monitoring Station 2-NOR000.20 August 5$^{th}$ - 6$^{th}$, 2009**

# 3.2 Discharge Monitoring Reports and Point Source Monitoring

## 3.2.1 Discharge Monitoring Reports

Discharge Monitoring Reports (DMR) for each of the individual permitted facilities discharging into the North Creek watershed were obtained for the period between 2001 and July 2011, and analyzed. **Table 3-10** summarizes the exceedances at permitted facilities:

**Table 3-10: Discharge Monitoring Report Summary**

| Permit No. | Facility Name | Parameter | Concentration Minimum | Concentration Average | Concentration Maximum | Quantity Average |
|---|---|---|---|---|---|---|
| VA0024147 | Fork Union Military Academy | Copper | - | 5 | 5 | - |
| | | E. coli | - | 1 | - | - |
| | | Flow | - | - | - | 1 |
| VA0081639 | Envoy at the Village | $Cl_2$, TOTAL | 2 | - | - | - |
| | | Dissolved Oxygen | 5 | - | - | - |
| | | Flow | - | - | - | 1 |
| | | pH | 1 | - | - | - |
| | | TKN, Dec-May | - | - | 1 | - |

## 3.2.2 Additional Point Source Monitoring

In the TMDL development process it was determined that there was a need for more nutrient data from the permitted facilities to determine their nutrient contribution to North Creek. Between 2012 and 2013 nutrient data was collected from both permitted facilities. Graphs detail each measured parameter.

- $NO_3$-N (Nitrate) concentrations ranged from 4.9 to 26.3 mg/L. $NO_2$-N (Nitrite) concentrations ranged between and 0.004 and 0.25 mg/L for $NO_2$-N (**Figure 3-28 and 3-29**). Both point sources had high nitrate and nitrite levels.

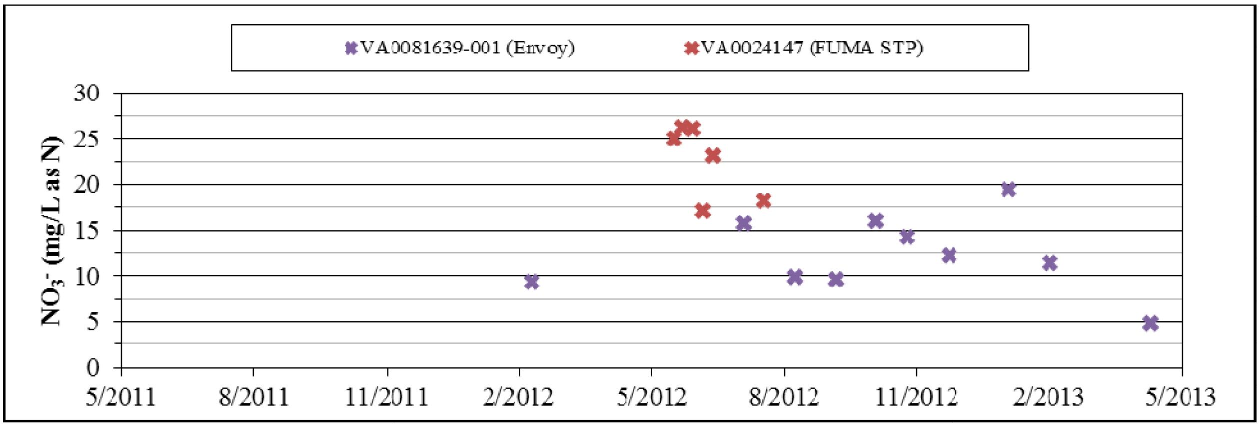



**Figure 3-28: Point Source Nitrate Measurements**

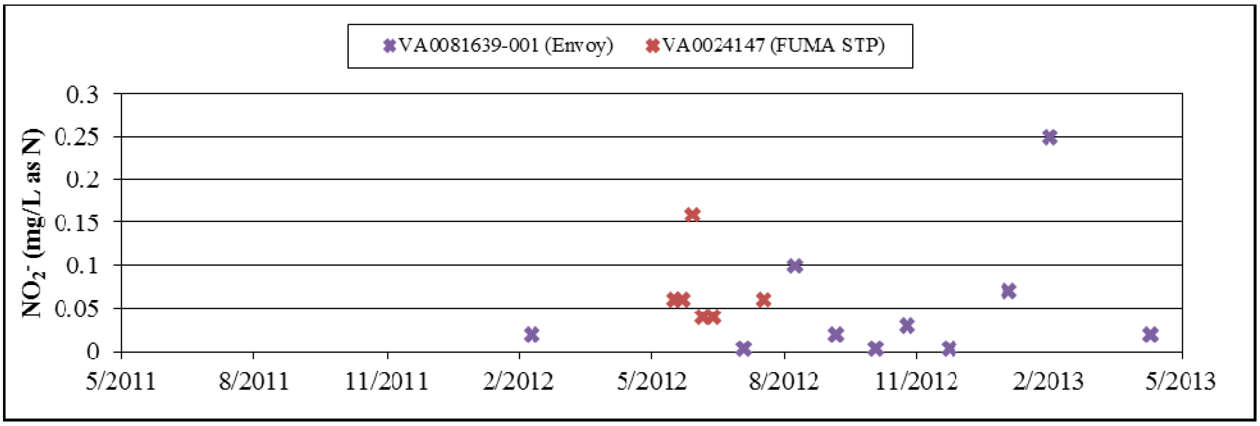



**Figure 3-29: Point Source Nitrite Measurements**

- Total Nitrogen (TN) concentrations ranged between 0.14 and 7.18 mg/L and were only available for Envoy (**Figure 3-30**). Total Nitrogen levels, just like the nitrate and nitrite levels, were very high.

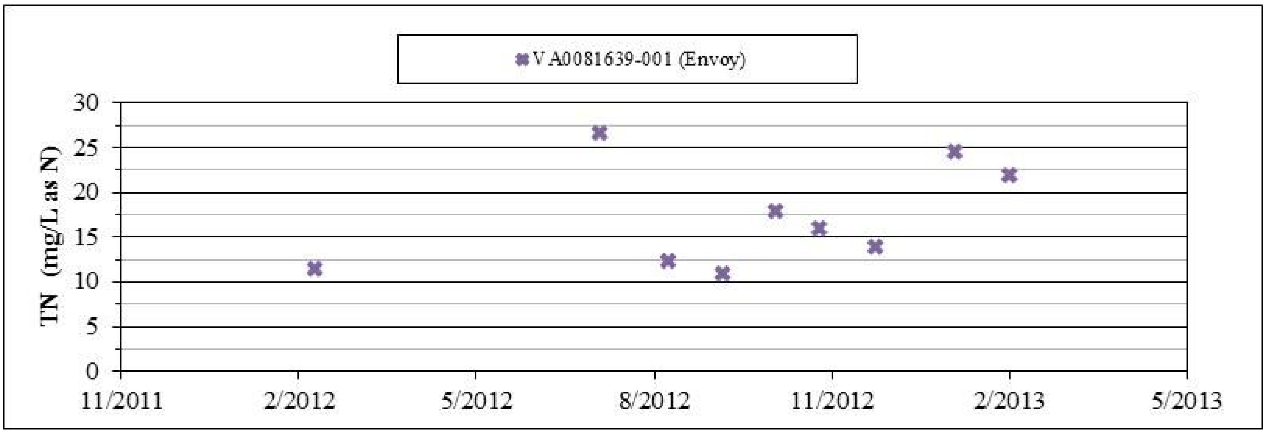



**Figure 3-30: Point Source Total Nitrogen Measurements**

➢ Ortho-phosphorus ($PO_4$-P) concentrations ranged between 0.11 and 4.5 mg/L (**Figure 3-31**). There are no DEQ screening values for ortho-phosphorous. The minimum detection limit for ortho-phosphorous is 0.01 mg/L. Concentrations of ortho-phosphorus were high for both point sources.

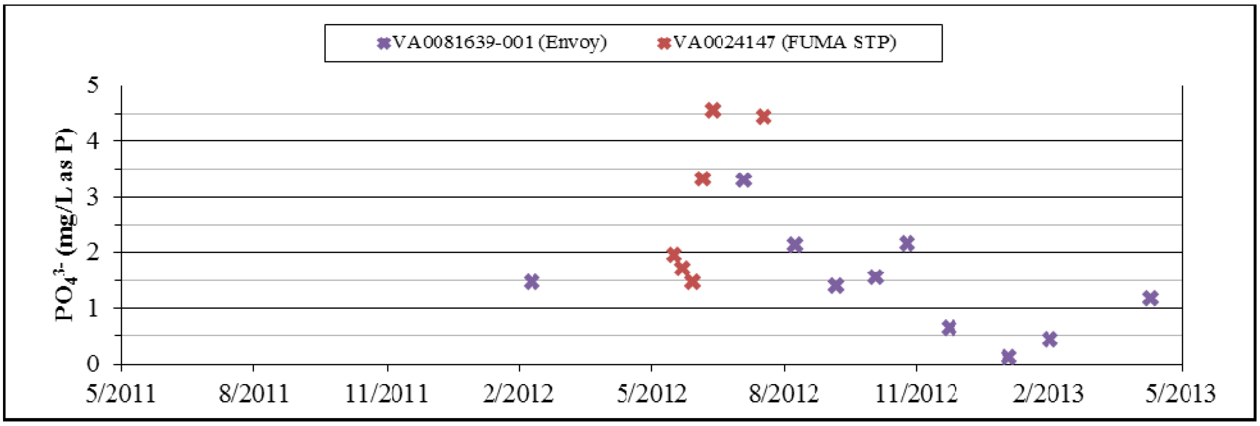



**Figure 3-31: Point Source Ortho-Phosphorus Measurements**

➢ Total Phosphorus (TP) concentrations ranged between 0.55 and 4.74 mg/L (**Figure 3-32**). TP concentrations were highest from both permitted facilities.

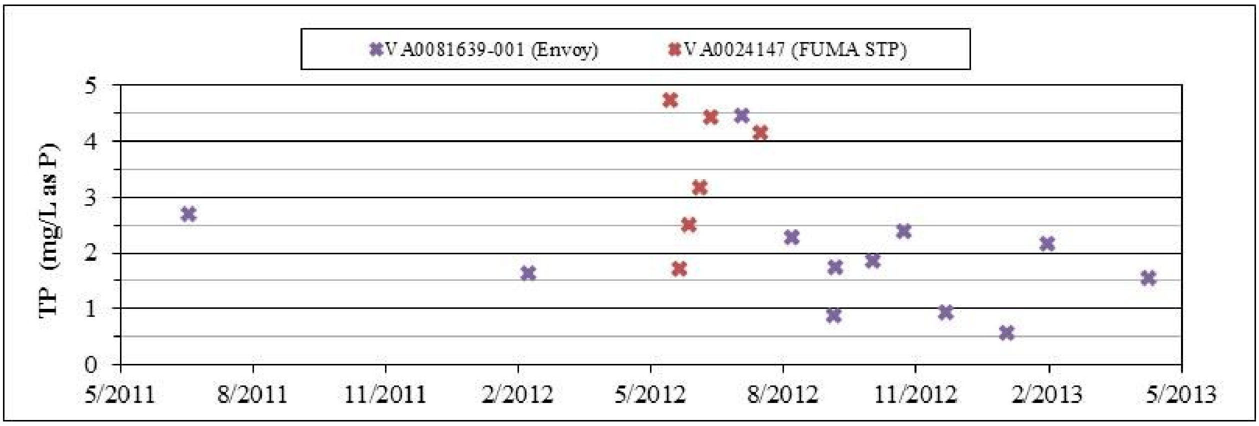



**Figure 3-32: Point Source Total Phosphorus Measurements**

After analyzing the nutrient monitoring data both in North Creek and from the point sources, it can be concluded that there is significant nutrient contribution to North Creek from the permitted facilities.

# 4.0 Stressor Identification Analysis

TMDL development for a benthic impairment requires identification of the pollutant stressor(s) affecting the benthic macroinvertebrate community. Stressor identification for the benthic macroinvertebrate community impaired segment of North Creek was performed using the available environmental monitoring and watershed characterization data discussed in previous sections. The stressor identification follows guidelines outlined in the EPA Stressor Identification Guidance (EPA, 2000).

Stressor identification for the Benthic TMDL on North Creek was completed using data available as of May, 2013. The identification of the most probable cause of biological impairment in North Creek was based on evaluations of candidate stressors that can potentially impact the river. The evaluation includes candidate stressors such as dissolved oxygen, temperature, pH, metals, nutrients, and sediment. Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed. Each stressor was then classified as one of the following:

**Non-stressor:** Stressor with data indicating normal conditions, without water quality standard exceedances, or without any apparent impact.

**Possible stressor**: Stressor with data indicating possible links to the benthic impairment, but without conclusive data to show a direct impact on the benthic community.

**Most probable stressor**: Stressor with conclusive data linking it to the poor health of the benthic community.

**Table 4-1** summarizes the results of the stressor analysis for North Creek.

| Table 4-1: Summary of Stressor Identification in North Creek |
|---|
| **Non-Stressors** |
| Instream Dissolved Heavy Metals |
| DO |
| pH |
| Temperature |
| **Possible Stressors** |
| None |
| **Most Probable Stressor(s)** |
| Sedimentation |
| Phosphorus |

## 4.1 Non-Stressors

### 4.1.1 Instream Heavy Metals

All available dissolved metals data (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc) indicated that their concentrations were below the acute and chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards.

Instream heavy metals do not appear to be adversely affecting the benthic macroinvertebrates in North Creek and are therefore classified as non-stressors.

### 4.1.2 Dissolved Oxygen

Benthic invertebrates and other aquatic organisms require a suitable range of dissolved oxygen conditions to survive close to or within the benthic sediments of rivers or streams. Decreases in instream oxygen levels can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. Based on grab and continuous measurements for dissolved oxygen, there was two exceedance of VA DEQ daily average standard (4.4 mg/L, station 2-NOR003.59 and 4.5 mg/L, station 2-NOR003.75). The continuous measurements for dissolved oxygen did not fall below 6.3 mg/L and showed a swing of only 1.8 at the station 2-NOR003.59, 1.6 mg/L at 2-NOR003.28 and 0.6 mg/L at 2-NOR000.20.

Dissolved oxygen does not appear to be adversely affecting the benthic macroinvertebrates in North Creek and is therefore classified as a non-stressor.

### 4.1.3 pH

Benthic invertebrates require a suitable range of pH conditions. Although these ranges may vary by invertebrate phylogeny, very high or very low pH values may result in a poor invertebrate assemblage comprised predominantly of tolerant organisms. The Virginia Class III water quality standards identify the acceptable pH for North Creek (6.0 – 9.0). Field measurements indicated adequate pH values in and upstream of the biologically impaired segment. There were three exceedances of the pH standards, but the majority of the samples fell within the water quality standard range.

The pH conditions do not appear to be adversely impacting benthic communities in North Creek and is therefore classified as a non-stressor.

### 4.1.4 Temperature

Benthic invertebrates require a suitable range of temperature conditions to survive in streams and rivers. High instream temperature values may result in an impaired invertebrate assemblage comprised predominantly of pollution-tolerant organisms. Based on grab and continuous measurements for temperature, data indicated no exceedance of VA DEQ criteria of 32°C. Continuous monitoring showed small daily swings in temperature.

The temperature conditions do not appear to be adversely impacting benthic communities in North Creek and is therefore classified as a non-stressor.

## *4.2 Most Probable Stressors*

### 4.2.1 Nutrients

Increased nutrient (nitrogen and phosphorus) concentrations can stimulate algal growth that may result in eutrophic conditions, high organic loading, and decreased dissolved oxygen levels in the early morning hours of the growing season. Excessive algal growth can impact the benthic macroinvertebrates present in the stream, causing some trophic groups to decline and others to increase in population. Increased periphyton growth prevents benthic macroinvertebrates from attaching to substrate, and the kinds of algae typically associated with eutrophication are undesirable sources of food (Voshell, 2002). In North Creek benthic impaired segment, total nitrogen (TN) and total phosphorus (TP) concentrations are elevated from sampling of the Fork Union Military Academy sewage treatment plant (STP) and the Envoy at the Village STP in the entire sampling period. After the confluence of the tributaries carrying the permitted facility effluent and North Creek (station 2-NOR003.28), the nutrient levels decreases somewhat but remain high. VA DEQ biologists observed excessive periphyton growth in the spring of 2008 and fall of 2010 at multiple sites during field visits to the impaired segment. The 2010 Integrated 305(b)/303(d) Assessment indicated abundant filamentous algae at both stations in the impaired segment. The average total nitrogen concentration in the impaired segment was 1.21 mg/L and the average total phosphorus concentration in the impaired segment was 0.31 mg/L.

Through its probabilistic monitoring program, VADEQ developed a risk scale based on nutrient concentrations and their potential for impacting benthic macroinvertebrate communities (via VSCI scores) based on data gathered from streams across the state of Virginia. **Tables 4-2** and **4-3** present the risk categories of their potential to impact VSCI scores and the corresponding nutrient ranges. The analysis also concluded that when the average total nitrogen concentrations exceed 2 mg/L and the average total phosphorus concentrations exceed 0.05 mg/L there is a high probability that the VSCI will not pass the minimum attainment threshold of 60.

**Table 4-2: VADEQ Total Nitrogen Risk Scale [1]**

| Risk Category | Total Nitrogen (mg/L) |
|---|---|
| Suboptimal Risk to Aquatic Life | >2 |
| Optimal Risk to Aquatic Life | <1 |

**Table 4-3: VADEQ Total Phosphorus Risk Scale[1]**

| Risk Category | Total Phosphorus (mg/L) |
|---|---|
| Suboptimal  Risk to Aquatic Life | >0.05 |
| Optimal Risk to Aquatic Life | <.02 |

[1] The risk scale values presented in Tables 4-2 and 4-3 do not represent nutrient criteria nor are intended for establishing TMDL endpoints. This is a risk assessment tool presented in Virginia's 2012 Integrated Report and is used in conjunction with an existing impairment. The values are thought to represent an increase in probability of impairment.

Using the TN risk scale, it is found that the average total nitrogen concentration is in the medium risk to aquatic life category. Using the TP risk scale, it is found the average total phosphorus is well above the 0.05 mg/L numeric value that through the analysis indicates a high probability that the TP levels found in North Creek will impede the benthic community in passing the minimum attainment threshold of 60. Therefore, phosphorus was identified as a probable stressor to the benthic community.

### 4.2.2 Sedimentation

The habitat scores for sedimentation were low throughout the impaired segment. In the impaired segment, sediment loads from agricultural and urban lands and the loss of riparian vegetation and decrease in bank stabilization cause instream erosion, which contributes greatly to the sediment load within the stream. This can lead to the increase of sedimentation and embeddedness. In Chapter 3, it is shown that over time, the bank stability and vegetative protection scores decline which indicate erosion is increasing. Also, the embeddedness and sediment deposition scores averaged at or below 10, indicating large quantities of sediment are moving through the stream and settling around the rocks, impeding the benthic community. Sedimentation reduces the available habitat for sensitive benthic macroinvertebrates and can cause the community to become impaired.

In addition to the habitat data indicating a sediment issue in North Creek, there are qualitative observations from monitoring staff which indicate sediment most probably the main stressor to the North Creek benthic community. In the 2007-2008 survey, at station 2-NOR003.59, the staff indicated "*the stream has unstable banks and a high rate of sediment deposition*". In the 2007 to 2008 survey, at station 2-NOR003.28, the staff described the stream as "*characterized by bedrock and cobble riffles that are embedded with sediment*". In addition to these descriptions DEQ staff visited sites upstream of these stations in February of 2012 and documented the instream erosion along the mainstem of North Creek as well a tributary. **Figures 4-1 to 4-3** are photos taken during the site visit. As seen in all photos, the banks are highly eroded and there is large quantity of suspended solids within the stream.

**Figure 4-1: North Creek mainstem upstream of confluence with unnamed tributary draining the Envoy at the Village STP.**

**Figure 4-2: North Creek mainstem downstream of confluence with unnamed tributary draining the Envoy at the Village STP.**

**Figure 4-3: Unnamed tributary draining the Envoy at the Village STP.**

Due to the low habitat scores in regards to sediment across all habitat monitoring stations in North Creek, and the qualitative evidence of in stream erosion and sedimentation, sediment is considered another probable stressor to the benthic community of North Creek.

## *4.3 Stressor Identification Summary*

The data and analysis presented in this report indicate that instream dissolved heavy metals, DO, pH, and temperature in the biologically impaired segment of North Creek are adequate to support a healthy invertebrate community, and are not stressors contributing to the benthic impairment.

Typically, high levels of periphyton and nutrients typically cause eutrophication in waterbodies, and an indicator of eutrophication is hypoxia, or the depletion of oxygen in water. However, in the sampling data there are no exceedances of the VADEQ dissolved oxygen minimum standard of 4.0 mg/L. The diurnal study for dissolved oxygen did not fall below 6.3 mg/L and showed a swing of 1.8 and 1.6 mg/L (at the impaired stations 2-NOR003.59 and 2-NOR003.28, respectively) and 0.6 mg/L (non-impaired station 2-NOR000.20). It should be noted that the diurnal DO study was done in August, when the largest point source (Fork Union Military Academy) is not operating at full capacity.

The lack of eutrophication evidence indicates that while phosphorus is a stressor to the benthic community, there is most likely an additional stressor, sediment, causing degradation in the benthic community. Therefore both phosphorus and sediment were selected as probable stressors.

# 5.0 TMDL Endpoint Identification – Reference Watershed Approach

TMDL development requires the determination of endpoints, or water quality goals/targets, for the impaired waterbody. TMDL endpoints represent stream conditions that meet water quality standards. Endpoints are normally expressed as the numeric water quality criteria for the pollutant causing the impairment. Compliance with numeric water quality criteria, such as a maximum allowable pollutant concentration, is expected to achieve full use support for the waterbody. However, not all pollutants have established numeric water quality criteria. In these cases, a reference watershed approach may be used to define the TMDL endpoint.

North Creek was initially included on the Virginia Section 303(d) list for violations of the General Standard (benthic impairment). As detailed in Chapter 4.0, sedimentation and excess phosphorus were identified as the most probable stressors causing the benthic impairment in the creek. Currently, Virginia has not adopted a numeric standard for sediment or for TP in free flowing streams. Therefore, a reference watershed approach was used to establish the numeric sediment and phosphorus TMDL endpoint for North Creek.

During the TMDL development process for North Creek, sediment was initially selected as the most probable stressor and a sediment TMDL was developed. However following additional data gathering and analysis, phosphorus was identified as a co-stressor for North Creek. The sediment TMDL was based on a larger watershed than the phosphorus TMDL (4,750 acres vs. 2,554 acres). At the time of the sediment TMDL development the VSCI scores were low enough at 2-NOR000.20 to warrant a longer impairment. Post sediment TMDL development, the impairment was shortened to the current length of 3.25 miles (because of sufficient VSCI scores in later monitoring). The following section details the selection of the reference watersheds for both the sediment and phosphorus TMDL development.

## 5.1 Reference Watershed Approach

The development of the endpoint for the North Creek watershed uses a reference watershed approach. Under the reference watershed approach, the TMDL endpoint for an impaired watershed is established based on conditions in a similar, but non-impaired reference watershed. In terms of benthic impairment caused by sedimentation and phosphorus, the TMDL endpoint is the total load in the adjusted reference watershed. Reduction of the total load in the impaired watershed to the level in the adjusted reference watershed is assumed to be sufficient for recovery of the benthic community in the impaired watershed.

Selection of an appropriate reference watershed is based on similarities in watershed characteristics such as soils, topography, land uses, and ecology. Similar watersheds help to ensure that the potential benthic aquatic communities are comparable. Similar watersheds also provide for similar watershed hydrology which influences pollutant loading rates to the stream.

## 5.2 Selected Reference Watershed(s)

The sediment TMDL for North Creek identified Holiday Creek as its reference watershed whereas the phosphorus TMDL identified a reference condition also on North Creek but located at a downstream unimpaired monitoring station (2-NOR000.20). **Table 5-1** summarizes important criteria considered in the selection of the reference watersheds for the North Creek.

**Table 5-1: Criteria Used in Reference Watershed Selection**

| Criteria | Relevance |
|---|---|
| Benthic Monitoring Data | Benthic Monitoring data is required to confirm the non-impairment status of the reference watershed |
| Ecoregion | The reference and impaired watersheds should belong to the same ecoregion to help ensure similarities in stream ecology. |
| Land Uses | The selected reference watersheds should reflect similar land use distributions. The water quality of streams in a watershed is greatly influenced by land use. Similar land use distributions help to establish achievable TMDL endpoints. |
| Soils | Soil composition influences watershed runoff, erosion, and stream ecology. |

| | |
|---|---|
| Watershed Size | The reference watershed should be similar in size and stream order to the impaired watershed since watershed area influences pollutant loading rates to the stream. |
| Location | Close proximity to the impaired watershed generally improves overall watershed similarity. In addition, the reference watershed should be near a weather station that may be used to characterize precipitation at both watersheds in order to standardize model simulations. |

The Holiday Creek watershed was selected as the reference watershed for the North Creek sediment TMDL development. The Holiday Creek reference watershed is located about 32 miles southwest of North Creek and is within the James River watershed. Both the North Creek and Holiday Creek watersheds are located entirely within the Piedmont ecoregion. The watersheds are comparable in size and stream order with the Holiday Creek watershed covering 5,478 acres and the North Creek covering 4,750 acres. **Figure 5-1** displays a map of the reference watershed and North Creek, along with the weather station (Louisa) used for modeling both watersheds.

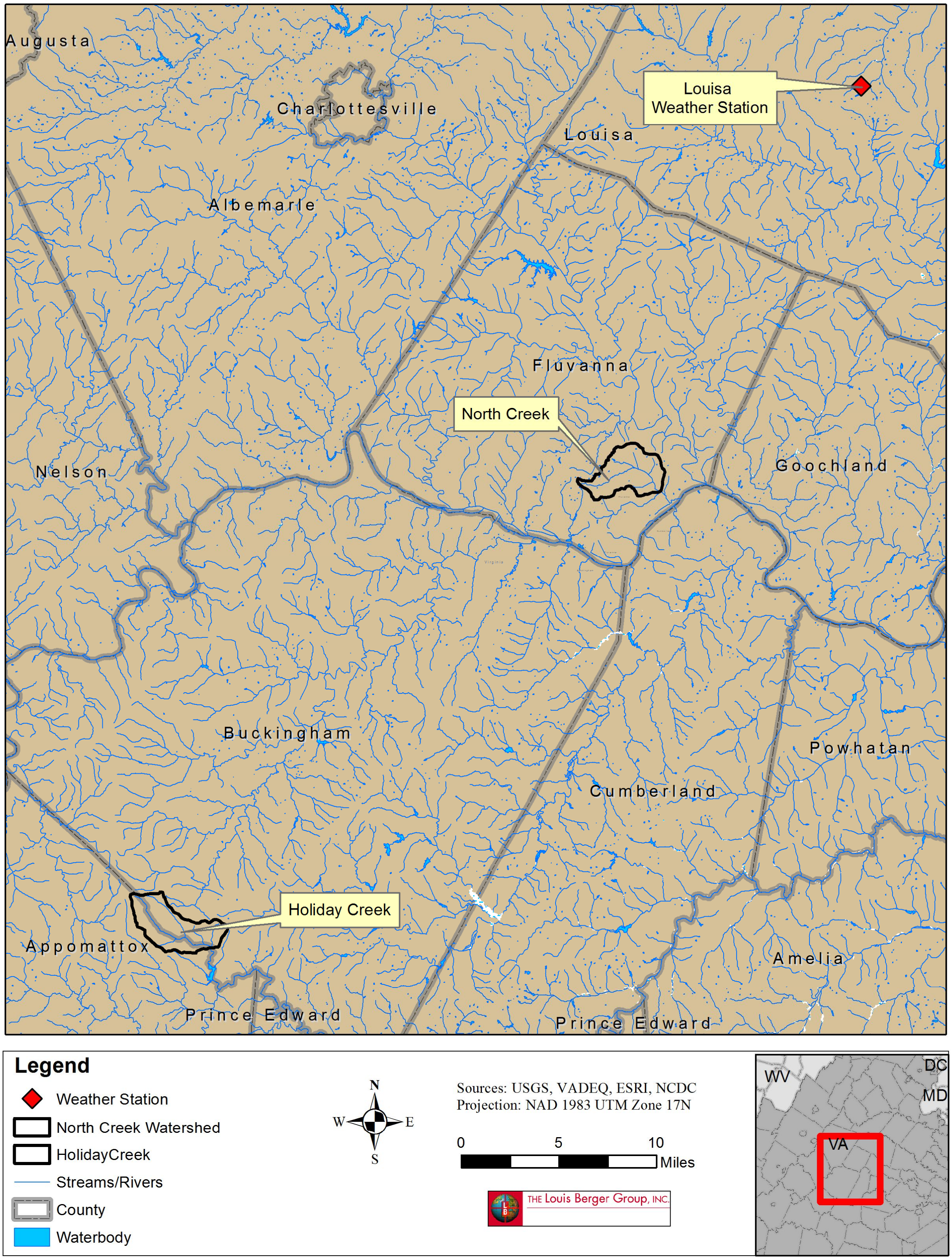



**Figure 5-1: Holiday Creek and North Creek Overview**

An extended North Creek watershed was selected as the reference watershed for the North Creek phosphorus TMDL development. At monitoring station 2-NOR000.20, the average VSCI score from 2007 to 2013 was 63 thus meeting the minimum attainment threshold of 60. The lowest observed TP value at station 2-NOR000.20, 0.06 mg/L, was selected as the TP endpoint for North Creek. The spring sample VSCI in the same timeframe was 72; this is well over the minimum attainment threshold of 60. An endpoint location on the same stream was selected because even though there is excessive nutrients in the upstream portions of the stream, the stream is able to assimilate the nutrients leading to benthic community recovery downstream at station 2-NOR000.20. **Figure 5-2** displays a map of the North Creek reference watershed and the North Creek impaired watershed.

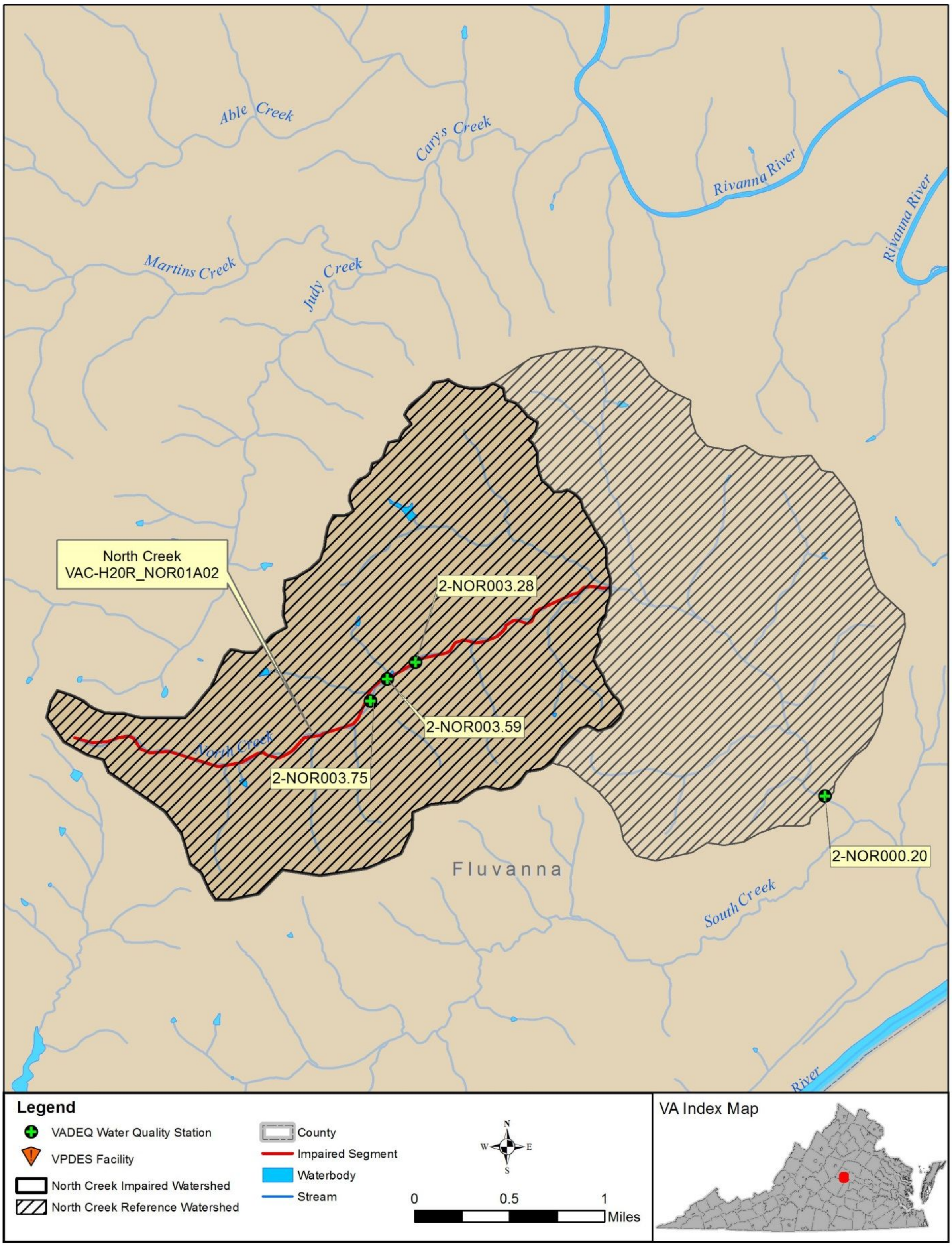



**Figure 5-2: North Creek Reference and North Creek Impaired Watershed Overview**

### 5.2.1 Benthic Monitoring Data

In order to confirm that the Holiday Creek watershed is unimpaired, VSCI data was obtained for stations along the Holiday Creek. **Figure 5-3** shows the VSCI scores for station 2-HOL003.15 on Holiday Creek. All VSCI scores are above the cutoff of 60 at station 2-HOL003.15.

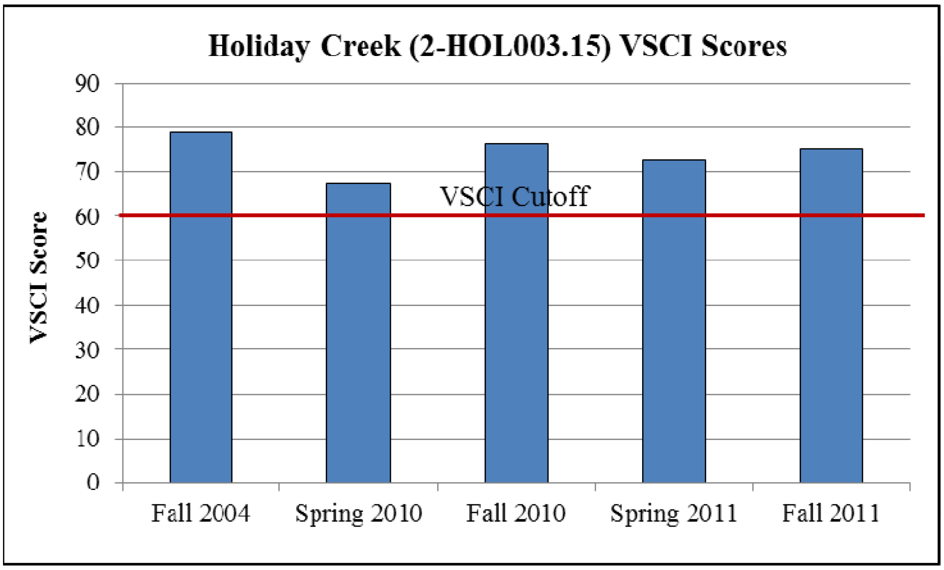



**Figure 5-3: Holiday Creek VSCI Scores**

The selected reference station on North Creek, 2-NOR000.20, has on average a VSCI score of 63, though some sampling dates in the past showed VSCI scores lower than 60. This is believed to be attributed to the additional stressor of sediment to the benthic community. **Figure 5-4** presents the VSCI scores for station 2-NOR000.20 from Spring 2007 to Spring 2013.

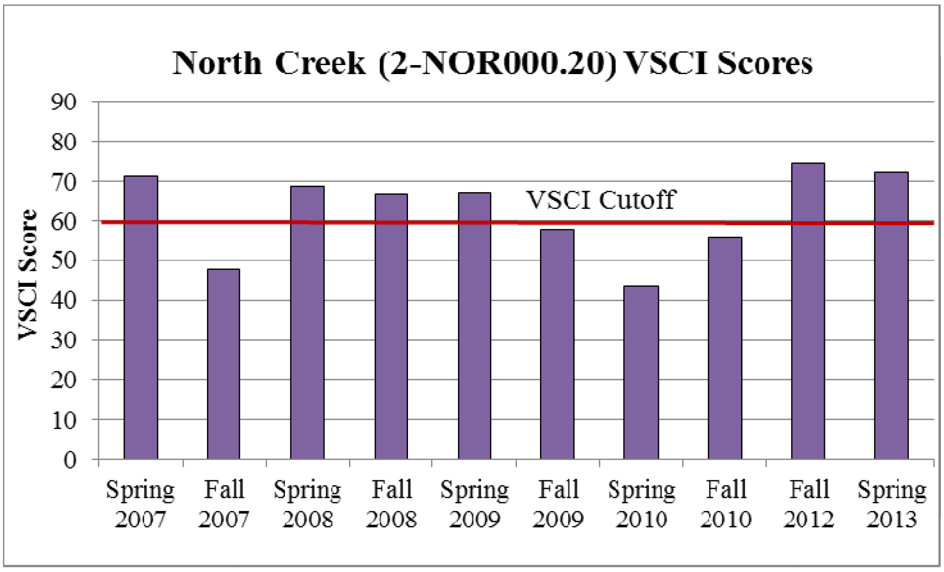



**Figure 5-4: North Creek VSCI Scores**

### 5.2.2 Land Use

A comparison of land use distributions in the North Creek sediment TMDL watershed and Holiday Creek reference watersheds is provided in **Table 5-2**. The dominant landuse in North Creek and Holiday Creek watersheds is forest, at 77% and 89%, respectively. Both watersheds have very similar landuse distributions, making Holiday Creek a good choice for a reference watershed.

**Table 5-2: Summary of Land Use Distributions for North Creek Sediment Watershed and Holiday Creek Reference Watersheds**

| Land Use Category | % of Total Watershed | |
|---|---|---|
| | North Creek Sediment Watershed | Holiday Creek |
| Developed | 4 | 3 |
| Agricultural | 14 | 4 |
| Forest | 77 | 89 |
| Water/Wetlands | 1 | 1 |
| Other* | 4 | 3 |

*Other includes: Scrub/Shrub, Grassland/Herbaceous, and Barren Land

A comparison of land use distributions in the North Creek phosphorus impaired and North Creek reference watersheds is provided in **Table 5-3**. The land uses are very similar, although the reference watershed has more forest and less agriculture than the impaired watershed.

| Table 5-3: Summary of Land Use Distributions for North Creek Phosphorus Impaired Portion and North Creek Reference Watersheds | | |
|---|---|---|
| Land Use Category | % of Total Watershed | |
| | North Creek TP Impaired | North Creek Reference |
| Developed | 4 | 3 |
| Agricultural | 21 | 14 |
| Forest | 69 | 77 |
| Water/Wetlands | <1 | 1 |
| Other* | 5 | 5 |
| *Other includes: Scrub/Shrub, Grassland/Herbaceous, and Barren Land | | |

### 5.2.3 Soils Distribution

A summary of the soils distributions for North Creek sediment watershed and Holiday Creek reference watershed is provided in **Table 5-4**. Hydrologic soil groups represent the different levels of soil infiltration capacity. The soil series in both the sediment TMDL watershed (North Creek) and the reference watershed (Holiday Creek), consist of soils of hydrogroups B and C, and therefore have moderate to slow infiltration rates. The soil hydrogroups match very closely.

| Table 5-4: Summary of Soil Distributions for North Creek Sediment TMDL Watershed and Holiday Creek Reference Watersheds | | |
|---|---|---|
| Hydrologic Group | % of Total Watershed | |
| | North Creek | Holiday Creek |
| B | 80 | 89 |
| B/D | 5 | - |
| C | 11 | 9 |
| C/D | <1 | 2 |
| D | 5 | - |
| (blank) | <1 | <1 |

A summary of the soils distributions for North Creek phosphorus impaired watershed and North Creek reference watershed is provided in **Table 5-5**. The soil series in both the impaired watershed (North Creek) and the reference watershed (North Creek Reference), consist of soils of hydrogroups B and C and D, and match very closely.

**Table 5-5: Summary of Soil Distributions for North Creek Phosphorus Impaired Portion and North Creek Reference Watersheds**

| Hydrologic Group | % of Total Watershed | |
|---|---|---|
| | North Creek TP Impaired | North Creek Reference |
| B | 81 | 80 |
| B/D | 2 | 5 |
| C | 8 | 10 |
| C/D | <1 | <1 |
| D | 8 | 5 |
| (blank) | <1 | <1 |

# 6.0 Pollutant Load Determination

As discussed in the previous section, a reference watershed approach was used to develop both the sediment and phosphorus TMDL for the benthic impaired North Creek watershed. The Holiday Creek reference watershed was selected as the reference watershed for the sediment TMDL (**Figure 5-1)** and a downstream unimpaired monitoring station on North Creek was selected as the reference condition for the phosphorus TMDL. The sediment loadings for the reference watershed and the lowest observed TP concentration (0.06 mg/L) at the reference station 2-NOR000.20 define the numeric TMDL endpoint for the impaired watershed. Therefore, in order to quantify the sediment and phosphorus load reductions necessary to achieve the designated aquatic life use for North Creek, loadings were determined for both the reference and impaired watersheds. Reduction of sediment and phosphorus loadings in the impaired watersheds to a level comparable to the unimpaired watershed loadings is assumed to be sufficient for recovery of the benthic community in the impaired watersheds.

## *6.1 Pollutant Source Assessment*

Sediment can be delivered to the stream via point sources or in the form of nonpoint source runoff. In addition, sediment (and phosphorus via adhesion to sediment) can be generated in the stream through the processes of scour and deposition, which are primarily a function of stream flow. During periods of high flow, erosion of the stream channel occurs. The eroded materials are typically deposited downstream as stream flow decreases. These processes may adversely impact the benthic macroinvertebrate community through the reduction of available habitat and the degradation of water quality.

Total phosphorus can be delivered to the stream from point sources located in the watershed, non-point source runoff from urban and agricultural lands, and non-point sources through seepage from groundwater in dissolved phosphorus forms. These processes adversely impact the benthic macroinvertebrate community through degradation of water quality.

Potential sediment and phosphorus sources are discussed in the next section followed by a presentation of the methodology used to quantify these sources for the development of the sediment and phosphorus endpoints and the TMDL.

### 6.1.1 Point Sources

Sediment loadings from point sources are attributable to the suspended solids present in discharge effluent. Phosphorus loading can also be attributed to point source effluent. There are currently two individual VPDES permitted facilities holding active permits (**Table 2-9**) in the North Creek watershed. DMR data was analyzed for both point sources to estimate the current point source sediment loading to North Creek. There are no individual VPDES permitted facilities holding active permits in the Holiday Creek watershed.

### 6.1.2 Nonpoint Sources

The erosion of land is dependent upon many factors including land use type and cover, soil type, and topography. The land use types in the North Creek watershed were characterized using the 2006 NLCD data, the soil types were characterized using the SSURGO database, and the associated hydrologic soil groups are presented in Section 2.0. Sediment and phosphorus loadings from generalized land use types present in the North Creek and Holiday Creek watersheds are discussed below.

**Forested Lands**

- Sediment loads from forested lands are typically low due to extensive root systems and vegetative cover that serve to stabilize soils. In addition, forest canopies intercept and dampen rainfall impacts.
- Total phosphorus loads from forested lands are typically low. This load is considered background condition.

**Agricultural lands**

- Sediment loads from agricultural lands tend to be elevated due to the exposure of soil that occurs in agricultural practices. Cropland and pastureland are the two sources of elevated sediment loads.

- Agriculture lands can be a dominant source for total phosphorus loads originating from excessive fertilizer application on cropland and pasturelands.

**Developed Lands**

- Developed lands consist of both pervious and impervious surfaces. Impervious surfaces are not subject to soil erosion, but sediment loads may result from the washoff of solids deposited on impervious surfaces. Sediment loads from developed lands tend to be high. In addition, elevated levels of uncontrolled stormwater runoff from developed lands contribute to streambank erosion as discussed below.
- Phosphorus loads from urban areas are mainly associated with excessive fertilizer application on areas such as yards, parks, playgrounds, and golf courses.

**Water/Wetlands**

- The amount of sediment loading from water and wetland areas typically is not significant.
- The amount of total phosphorus loading from water and wetland areas typically is not significant.

**Barren Lands**

- Transitional lands represent areas of sparse vegetative cover often due to land use activities such as forest clear-cuts and construction lands. Due to increased levels of soil exposure, sediment loads from transitional lands are typically high.

**Groundwater Seepage**

- Non-point sources entering through seepage include dissolved inorganic and/or organic phosphorus forms and originate from agricultural phosphorus application and septic systems. Both sources have generally a low impact on total phosphorus levels in the seepage because of the high capacity of soils to precipitate out phosphorus with calcium and to adsorb phosphorus to iron or aluminum oxides/hydroxides.

### 6.1.3 Instream Bank Erosion

Sediment derived from instream bank erosion is also dependent upon numerous watershed characteristics. Land use types present in the watershed may affect hydrology. In particular, highly developed lands may lead to increased stream flows that erode the stream channel and banks. Likewise, watersheds defined by steep topography may experience high levels of runoff that cause instream erosion. The level of instream erosion is dependent on the erodibility of the soil, normally defined as the soil K factor.

## *6.2 Technical Approach for Estimating the Land-Based Sediment and Instream Erosion Loads*

For the purpose of TMDL development, annual sediment and phosphorus loadings from non-point sources were determined in the North Creek and Holiday Creek watersheds using the Generalized Watershed Loading Functions (GWLF) model via a software program called BasinSim (Dai, 2000). GWLF was developed for estimating stream flow, sediment, and nutrient loads from ungauged watersheds and has been applied successfully to develop TMDLs in Virginia and other States. The GWLF model is applied to develop the land-based sediment loads in North Creek and Holliday Creek. Even though the model was developed for ungauged watersheds, it is first calibrated for hydrology in the Holiday Creek watershed using the observed flow at USGS station 02038850. Since there are no observed flow stations in the impaired North Creek watershed, the hydrology parameterization developed during the hydrology calibration in the Holiday Creek watershed is transferred to the North Creek watershed to generate the streamflow time series. The model is then applied to both watersheds to develop the existing land-based sediment loads in the North Creek sediment watershed and the Holiday Creek watershed and to develop the existing land-based phosphorus loads in the North Creek impaired watershed and the North Creek reference watershed. Instream erosion is developed separately from the GWLF model using a spatial technique developed by Evans et al.

(2003) based on watershed characteristics. The sediment land-based loads are then added to the instream erosion loads to generate the total sediment load for the North Creek and Holiday Creek watershed. The sediment loadings for the Holiday Creek reference watershed were then adjusted to reflect the size of the sediment watershed and develop the TMDL sediment endpoint and the sediment TMDL. A similar approach was applied for the development of the phosphorus TMDL, where the phosphorus loading from the reference watershed was then adjusted to reflect the size of the impaired watershed. The following sections provide details on all the steps of this technical approach.

### 6.2.1 GWLF Model Description

GWLF is a time variable model that simulates hydrology, sediment, and nutrient loadings on a watershed basis. Observed daily precipitation data is required in GWLF as the basis for water budget calculations. Surface runoff, evapotranspiration and groundwater flows are calculated based on user specified parameters. Stream flow is the sum of surface runoff and groundwater discharge. Surface runoff is computed using the Soil Conservation Service Curve Number Equation. Curve numbers are a function of soils and land use type. Evapotranspiration is computed based on the method described by Hamon (1961) and is dependent upon temperature, daylight hours, saturated water vapor pressure, and a cover coefficient. Groundwater discharge to the stream is calculated using a lumped parameter for unsaturated and shallow saturated water zones. Infiltration to the unsaturated zone occurs when precipitation exceeds surface runoff and evapotranspiration. Percolation to the shallow saturated zone occurs when the unsaturated zone capacity is exceeded. The shallow saturated zone is modeled as a linear reservoir to calculate groundwater discharge. In addition, the model allows for seepage to a deep saturated zone.

Erosion, sediment, and nutrient loading are a function of the land source areas present in the watershed. Multiple source areas may be defined based on land use type, the underlying soils type, and the management practices applied to the lands. Sediment loadings from each source area are summed to obtain a watershed total. The Universal Soil Loss Equation (USLE) is used to compute erosion for each source area and sediment and phosphorus delivery ratios are applied to determine the sediment and phosphorus loadings to the stream (USLE, Wischmeier and Smith, 1978), and are expressed as:

a =R K LS C P

Where:
a =Average annual soil loss in tons per acre per year
R =Rainfall/runoff erosivity
K =Soil erodibility
LS = Field slope length and steepness
C =Cover/management factor
P =Conservation practice factor

The R factor is an expression of the erosivity of rainfall and runoff in the area of interest; the R factor increases as the amount and intensity of rainfall increases. The K factor represents the inherent erodibility of the soils in the area of interest under standard experimental conditions. The K factor is expressed as a function of the particle-size distribution, organic-matter content, structure, and permeability of the soils. The LS factor represents the effect of topography, specifically field slope length and steepness, on rates of soil loss at a particular site. The LS factor increases with field slope length and steepness due to the resulting accumulation and acceleration of surface runoff as it flows downslope. The C factor represents the effects of surface cover and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at the area of interest. The C factor decreases as surface cover and soil biomass increase. The P factor represents the effects of supporting conservation practices, such as contouring, buffer strips, and terracing, on soil loss at the area of interest.

### 6.2.2 Instream Erosion

Instream erosion in North Creek was calculated using a spatial technique developed by Evans et al. (2003) that estimates streambank erosion based on watershed characteristics. Using this method, a watershed-specific lateral erosion rate is calculated as follows:

$$LER = aQ^{0.6}$$

Where:
LER = an estimated lateral erosion rate, expressed as meters per month
a = an empirically-derived “erosion potential factor”

Q = monthly stream flow, expressed as cubic meters per second.

The *'a'* factor is computed based on a wide variety of watershed parameters including the fraction of developed area of the watershed, average field slope, mean soil erodibility (K factor), average curve number value, and the mean livestock density for the watershed.

$$a = (0.00147*PD) + (0.000143*AD) + (0.000001*CN) + (0.000425*KF) + (0.000001*MS) - 0.00016$$

Where:
PD = fraction developed land
AD = animal density measured in animal equivalent units/acre
CN = area-weighted runoff curve number value
KF = area-weighted K factor
MS = mean field slope

The fraction of developed land in the North Creek watershed was obtained from 2006 NLCD data. The mean soil erodibility K factor and mean field slope of the watershed were computed from the SSURGO database. The average watershed curve number was developed based on curve numbers applied in the GWLF model. Livestock densities for the watershed were based on county livestock inventories form the 2007 USDA agricultural census. The 'a' factors for the North Creek reference and impaired watersheds were computed.

LER values were calculated using predicted stream flow from the GWLF model. Monthly sediment loads from streambank erosion (kg/month) were then calculated as the product of the LER (meters/month), total perennial stream length (meters), average streambank height (meters), and average soil bulk density (kg/m$^3$). The total stream length for North Creek was obtained from the National Hydrography Dataset (NHD, 2002). Bank height was estimated using field survey results of the North Creek watershed. Mean soil bulk density was obtained from the SSURGO database. Annual sediment loads from streambank erosion were computed as the summation of monthly loads.

### 6.2.3 Point Source Loadings

The daily and yearly sediment point source loadings for the individually permitted facilities were computed based on the average flow and the average total suspended solids concentration for each facility. The TSS loads of individually permitted facilities within the North Creek watershed are shown in **Table 6-1**. There are no point sources within the Holiday Creek reference watershed.

**Table 6-1: TSS Loads for Individual Permitted Facilities in the North Creek Watershed**

| Facility Name | Existing TSS Load (kg/day)* | Existing TSS Load (tons/year)* | Allocated TSS Load (kg/day)** | Allocated TSS Load (ton/year)** |
|---|---|---|---|---|
| Envoy at the Village | 0.15 | 0.06 | 2.27 | 0.91 |
| Fork Union Military Academy | 0.58 | 0.24 | 11.24 | 4.52 |
| **Total** | **0.74** | **0.30** | **13.51** | **5.44** |

* Based on DMR reported average flow and average concentration (2007-2011)

** Based on facility design flow and concentration of 30 mg/ L

The existing daily and yearly TP point source loadings for the individual permitted facilities were computed based on the average flow and the average TP concentration for each facility. The allocated TP loads were computed based on the design flow and a TP concentration of 0.5 mg/L for each facility. The 0.5 mg/L TP concentration was selected through discussions with VADEQ TMDL and permit staff as well as staff from the individual permitted facilities. This concentration was deemed achievable by each point source and in conjunction with reductions from the non-point sources will achieve the TP endpoint of 0.06 mg/L. The TP loads of individual permitted facilities within the North Creek watershed are shown in **Table 6-2**.

**Table 6-2: TP Loads for Individual Permitted Facilities in the North Creek Watershed**

| Facility Name | Existing TP Load (lb/day)* | Existing TP Load (lb/year)* | Allocated TP Load (lb/day)** | Allocated TP Load (lb/year)** |
|---|---|---|---|---|
| Envoy at the Village | 0.13 | 49.13 | 0.08 | 30.05 |
| Fork Union Military Academy | 0.85 | 311.96 | 0.41 | 148.74 |
| **Total** | **0.98** | **361.09** | **0.49** | **178.79** |

* Based on DMR reported average flow and average concentration (2007-2011)

** Based on facility design flow and facility concentration of 0.5 mg/ L

## 6.3 GWLF Model Setup and Calibration

### 6.3.1 GWLF Model Development

GWLF model simulations were performed for 2002 to 2010 in order to cover the period of more recent biomonitoring assessments that resulted in the impairment listing for the North

Creek. In addition, the eight year simulation period accounts for both seasonal and annual variations in hydrology and sediment/phosphorus loading. Models were developed for both the reference and impaired watersheds. Model simulations were performed using BasinSim 1.0, which is a Windows interface program for GWLF that facilitates the creation of model input files and processing of model output.

As stated previously, under the reference watershed approach the TMDL endpoint is based on sediment loadings for the Holiday Creek reference watershed and the TMDL endpoint for phosphorus was based on a reference condition in a downstream location on North Creek. Since the reference watersheds are larger than the North Creek TMDL watersheds, pollutant loadings for the reference watershed were adjusted to reflect the size of the TMDL watershed. This was accomplished by running the GWLF model for an area-adjusted reference watershed. The area of each land use in the reference watershed was multiplied by the ratio of the overall area of the TMDL watershed to its reference watershed.

### 6.3.2 Weather Data

Daily precipitation and temperature data were obtained from Louisa station and data recorded from 2002-2010 were used for model simulations. This weather station is located within 55 miles from Holiday Creek watershed and within 20 miles from North Creek, and thus provided the most accurate precipitation and temperature coverage available for the two watersheds.

### 6.3.3 Model Input Parameters

In addition to weather data, GWLF requires specification of input parameters relating to hydrology, erosion, and sediment yield. In general, Appendix B of the GWLF manual (Haith et al., 1992) served as the primary source of guidance in developing input parameters. Runoff curve numbers and USLE erosion factors are specified as an average value for a given source area. The 2006 NLCD land use types present in the two watersheds (**Table 6-3** and **6-4**) were used to define model source areas. As necessary, GIS analyses were used to obtain area weighted parameter values for each given source area.

| Table 6-3: Land Use Distribution Used in GWLF Model for the North Creek Sediment TMDL Watershed and Holiday Creek Watersheds | | | |
|---|---|---|---|
| **General Land Use Category** | **NLCD 2006 Land Use Category** | **North Creek (acres)** | **Holiday Creek (acres)** |
| Developed | Developed High Intensity | 4.0 | 0.0 |
| | Developed Medium Intensity | 10.3 | 0.0 |
| | Developed Low Intensity | 18.4 | 2.0 |
| | Developed Open Space | 129.7 | 123.0 |
| Agricultural | Cultivated Crops | 6.5 | 17.5 |
| | Pasture/Hay | 678.3 | 213.8 |
| Forest | Deciduous Forest | 2,770.6 | 3,344.8 |
| | Evergreen Forest | 694.2 | 1,104.3 |
| | Mixed Forest | 174.7 | 440.8 |
| Other | Grassland/Herbaceous | 44.2 | 61.8 |
| | **Total** | **4,531.0** | **5,308.0** |

| Table 6-4: Land Use Distribution Used in GWLF Model for the North Creek TP Impaired and North Creek Reference Watersheds | | | |
|---|---|---|---|
| **General Land Use Category** | **NLCD 2006 Land Use Category** | **North Creek TP Impaired (acres)** | **North Creek Reference (acres)** |
| Developed | Developed High Intensity | 4.0 | 4 |
| | Developed Medium Intensity | 10.1 | 10.1 |
| | Developed Low Intensity | 18.1 | 19.3 |
| | Developed Open Space | 79.8 | 121.8 |
| Agricultural | Cultivated Crops | 6.5 | 6.5 |
| | Pasture/Hay | 528.4 | 665.6 |
| Forest | Deciduous Forest | 1,376.8 | 2,760.1 |
| | Evergreen Forest | 328.5 | 679.4 |
| | Mixed Forest | 67.1 | 167.6 |
| Other | Grassland/Herbaceous | 28.5 | 44.3 |
| | **Total** | **2,447.8** | **4,478.7** |

Runoff curve numbers were developed for each model source area in the watershed based on values published in the NRCS GWLF manual (Dai *et al.*, 2000). SSURGO soils GIS coverages were analyzed to determine the dominant soil hydrologic groups for each model source area. Evapotranspiration cover coefficients were developed based on values provided in the GWLF manual (Dai *et al.*, 2000) for each model source area. Average watershed monthly evapotranspiration cover coefficients were computed based on an area weighted method. Initialization and groundwater hydrology parameters were set to default values recommended in the GWLF manual.

USLE factors for soil erodibility (K), length-slope (LS), cover and management (C), and supporting practice (P) were derived from multiple sources based on data availability. Average KLSCP values for model source areas were determined based on GIS analysis of soils and topographic coverages as well as literature review. The rainfall erosivity coefficient was determined from values given in the GWLF manual. The sediment delivery ratio was computed directly in BasinSim.

In BasinSim, developed lands include impervious surfaces that are not subject to soil erosion. Rather, sediment loads from developed lands result from the buildup and washoff of solids deposited on the surface. Therefore, sediment loads from developed lands were not modeled using the USLE. Instead, sediment loads from developed lands were computed based on typical loading rates from developed lands (Horner et al., 1994, Shaver et al., 2007). **Table 6-5** shows the sediment loading rates used in this TMDL.

**Table 6-5: Sediment Loading Rates for Developed Land in the North Creek Watershed**

| Developed Lands | TSS (lb/ac-yr)* | TSS (metric ton/ha-yr) |
|---|---|---|
| Developed, Low intensity | 65 | 0.0729 |
| Developed, Med Intensity | 250 | 0.2802 |
| Developed, High Intensity | 420 | 0.4708 |
| Developed, Open Space | 3 | 0.0034 |

*Based on literature values: Fundamentals of Urban Runoff Management (Horner et al., 1994, Shaver et al., 2007)

### 6.3.4 Hydrology Calibration

GWLF was originally developed as a planning tool for estimating nutrient and sediment loadings on a watershed basis. Designers of the model intended for it to be implemented without calibration. Nonetheless, comparisons were made between predicted and observed stream flow for the reference watershed to ensure the general validity of the model.

The USGS station 02038850 located on Holiday Creek in Appomattox/Buckingham County was selected for hydrology calibration based on the period of available monitoring data, its unimpaired watershed, and the proximity of the gauge to the weather station used to develop the model precipitation inputs (Section 5).

GWLF parameters relating to hydrology were calibrated based on the flow data collected at USGS station 02038850. The groundwater seepage coefficient and the unsaturated zone available water capacity were adjusted to obtain a best fit with observed data. A visual comparison between observed and predicted flow is shown for Holiday Creek reference watershed (**Figure 6-1**).

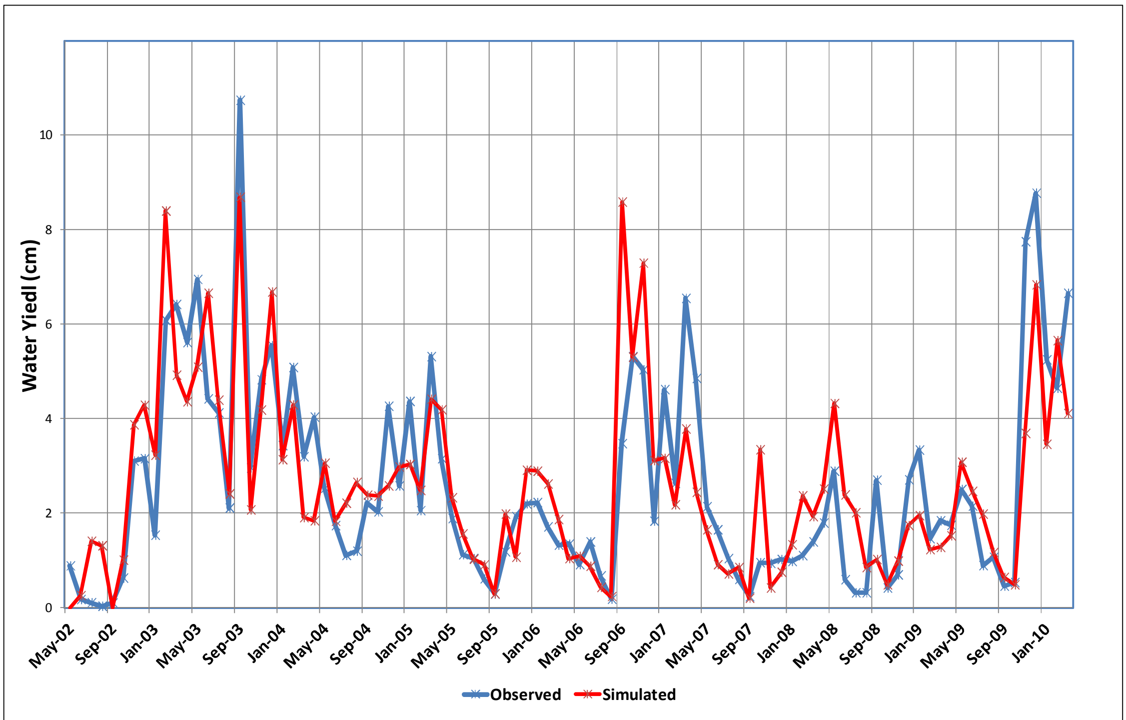



**Figure 6-1: Hydrology Calibration Observed v. Simulated for the Holiday Creek Watershed**

The modeler's confidence in the accuracy of the simulation results is usually exercised by a graphical comparison between observed and predicted results. A graphical comparison between observed and predicted results is imperative and provides the first check of the accuracy of the predicted values. However, it is meant to be the first check, since its accuracy strongly depends on the scale of the presented results. Therefore, the accuracy of the simulation results can be overstated and can lead to wrong conclusions. Two statistical measures for the evaluation of the predicted results were selected. The linear regression analysis is a valuable tool for the evaluation of predicted results. It is a method for fitting an equation to a set of data using the principle of least squares to reduce the sum of the squares of the errors (McCuen, 1998). Its reliability can be tested by the coefficient of determination ($R^2$). The best fit is achieved when $R^2$ is one. The percent error between the total simulated and observed flow is another helpful statistical method for evaluation of the overall water balance during the simulation period. The results of both evaluation tools are presented in **Table 6-6**. **Figure 6-2** depicts the resulting R-Square between observed and simulated flow. The percent error refers to the percent difference between the total (summed) observed flow and simulated flow for the entire modeling period.

**Table 6-6: Hydrology Calibration Statistics**

| Statistic | Holiday Creek Watershed |
|---|---|
| R Squared ($R^2$) | 0.644 |
| % Error | 0.72% |

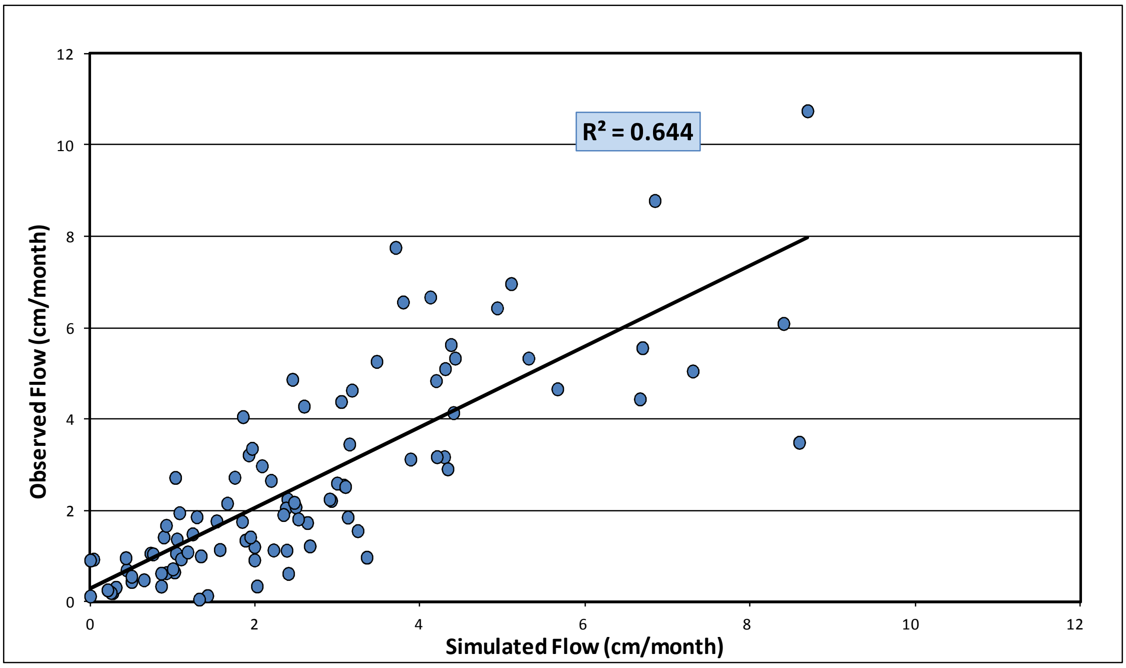



**Figure 6-2: Hydrology Calibration – R-Square Results for the Holiday Creek Watershed**

As mentioned previously, North Creek does not have a flow gauge and thereby does not have an observed dataset to calibrate against. The hydrology parameterization developed for the calibration of the Holiday Creek is transferred to the North Creek watershed using the same simulation period used for the reference watershed.

## 6.4 Sediment Total Load Estimates

### 6.4.1 Sediment Loads from Point Sources

Existing sediment loads from point sources in the North Creek watershed are outlined in Section 6.2.3.

### 6.4.2 Sediment Loads from Nonpoint Sources

The hydrologically calibrated model was used to estimate sediment loadings from each source area in the North Creek impaired and Holiday Creek reference watersheds. Based on the eight year simulation period from 2002-2010, average annual sediment loads were computed for each modeled land source in each watershed. These results as the adjusted area weighted loads for the reference watershed are presented in **Table 6-7.**

**Table 6-7: North Creek Average Annual Sediment Loads from Land Sources (tons/yr)**

| Source | Impaired Watershed | Reference Watershed | Area Adjusted Reference Watershed |
|---|---|---|---|
| Grassland/Herbaceous[1] | 3.8 | 0.0 | 0.0 |
| Deciduous Forest[1] | 29.2 | 34.0 | 29.5 |
| Evergreen Forest[1] | 7.3 | 11.2 | 9.7 |
| Mixed Forest[1] | 1.8 | 6.1 | 5.3 |
| Pasture/Hay[1] | 41.7 | 30.6 | 26.6 |
| Row Crop[1] | 4.4 | 18.9 | 16.4 |
| Developed, Low intensity[2] | 0.6 | 0.1 | 0.05 |
| Developed, Med Intensity[2] | 1.3 | 0.0 | 0.0 |
| Developed, High Intensity[2] | 0.8 | 0.0 | 0.0 |
| Developed, Open Space[2] | 0.2 | 0.2 | 0.15 |
| **Total** | **91.2** | **101.0** | **87.7** |

[1] Based on model simulations using GWLF
[2] Based on sediment loading rates

### 6.4.3 Sediment Loads from Instream Erosion

Instream erosion was estimated based on the streambank lateral erosion rate equation introduced by Evans et al. (2003), as described in Section 6.2.2. The 'a' factor used in the streambank erosion equation was computed using watershed specific data for the impaired and reference watersheds. Computed 'a' factors and annual sediment loads from streambank erosion are presented in **Table 6-8**.

**Table 6-8: Annual Instream Erosion Estimates**

| Watershed | Computed 'a' Factor | Instream Erosion (tons/yr) |
|---|---|---|
| Impaired Watershed | 8.817E-05 | 10.3 |
| Reference Watershed | 7.715E-05 | 5.6 |
| Reference Watershed (Area Adjusted) | 6.379E-05 | 5.0 |

### 6.4.4 Existing Sediment Loadings – All Sources

In summary, average annual sediment loads for the North Creek impaired and reference watersheds were determined as follows:

- Erosion and sediment yield from land sources were modeled using GWLF.
- Instream bank erosion was computed based on the method described by Evans et al. (2003).
- An area-weighted percentage of the land based and bank erosion sediment load was used to partition sediment loading attributed to other sources.

Average annual sediment loads from all sources for the North Creek impaired and reference watersheds are summarized in **Table 6-9**. The total existing sediment load in the impaired watershed is 101.8 tons per year. The area-adjusted reference watershed load of 92.7 tons per year represents the TMDL endpoint.

| Table 6-9: North Creek Average Annual Sediment Loadings (tons/yr) | | | |
|---|---|---|---|
| **Source** | **Impaired Watershed** | **Reference Watershed** | **Adjusted Reference Watershed** |
| Grassland/Herbaceous | 3.8 | 0.0 | 0.0 |
| Deciduous Forest | 29.2 | 34.0 | 29.5 |
| Evergreen Forest | 7.3 | 11.2 | 9.7 |
| Mixed Forest | 1.8 | 6.1 | 5.3 |
| Pasture/Hay | 41.7 | 30.6 | 26.6 |
| Row Crop | 4.4 | 18.9 | 16.4 |
| Developed, Low intensity | 0.59 | 0.06 | 0.05 |
| Developed, Med Intensity | 1.3 | 0.0 | 0.0 |
| Developed, High Intensity | 0.8 | 0.0 | 0.0 |
| Developed, Open Space | 0.19 | 0.19 | 0.15 |
| Instream Erosion | 10.3 | 5.6 | 5.0 |
| Point Sources | 0.3 | 0.0 | 0.0 |
| **Total** | **101.8** | **106.6** | **92.7** |

Reduction of sediment loading in the impaired watershed to the level computed for the area-adjusted reference watershed is expected to restore support of the aquatic life use for the North Creek.

## *6.5 Phosphorus Total Load Estimates*

The hydrologically calibrated model was used to estimate phosphorus loadings from each source area in the North Creek impaired and North Creek reference watersheds. Existing phosphorus loads from point sources in the North Creek watershed are outlined in Section 6.2.3. Based on the eight year simulation period from 2002-2010, average yearly phosphorus loads were computed for each modeled land source in each watershed. **Table 6-10** presents the yearly average phosphorus loads from land based sources, groundwater, and the point sources**.**

| Table 6-10: North Creek Average Daily Phosphorus Loads (lb/year) | | | |
|---|---|---|---|
| **Source** | **Impaired Watershed** | **Reference Watershed** | **Area Adjusted Reference Watershed** |
| Grassland/Herbaceous | 6.8 | 8.4 | 6.8 |
| Deciduous Forest | 20.5 | 35.7 | 20.5 |
| Evergreen Forest | 4.4 | 7.9 | 4.4 |
| Mixed Forest | 0.9 | 1.8 | 0.9 |
| Pasture/Hay | 132.5 | 125.5 | 29.4 |
| Scrub/Shrub | 5.3 | 4.9 | 5.3 |
| Cultivated Crops | 1.3 | 2.0 | 0.3 |
| Developed, Low intensity | 6.4 | 4.6 | 1.4 |
| Developed, Med Intensity | 14.3 | 9.9 | 3.2 |
| Developed, High Intensity | 8.6 | 6.0 | 1.9 |
| Developed, Open Space | 75.0 | 78.9 | 16.6 |
| Groundwater | 148.0 | 272.1 | 148.0 |
| Point Sources | 361.1 | 361.1 | 187.3 |
| **Total** | **785.1** | **918.8** | **426.0** |

Reduction of phosphorus loading in the impaired watershed to the level computed for the area-adjusted reference watershed is expected to restore support of the aquatic life use for the North Creek.

# 7.0 TMDL Allocation

The purpose of TMDL allocation is to quantify pollutant load reductions necessary for each source to achieve water quality standards. Sediment and Total Phosphorus (TP) were identified as primary stressors to the benthic community in the North Creek impaired watershed and a reference watershed approach was used for TMDL development. The total average annual sediment and phosphorus loadings for the area-adjusted reference watershed represent the TMDL endpoints for the North Creek impaired watershed. Reduction of sediment and phosphorus loadings in the impaired watershed to the level computed for the area-adjusted reference watershed is expected to restore support of the aquatic life use for North Creek (**Table 6-9** and **6-10**).

## *7.1 Basis for TMDL Allocations*

Sediment TMDL allocations for the North Creek impaired watershed were based on the following equation.

$$TMDL = WLA + LA + MOS$$

Where:

TMDL = Total Maximum Daily Load (Based on the area-adjusted reference watershed sediment load)

WLA = Wasteload Allocation

LA = Load Allocation

MOS = Margin of Safety

The wasteload allocation represents the sediment loading allocated to point sources. The load allocation represents the sediment loading allocated to nonpoint sources. The margin of safety is a required TMDL element to account for uncertainties in TMDL development.

The North Creek TMDL allocation scenarios presented in the next section show the effects of the sediment load reduction from point and nonpoint sources in the watershed.

### 7.1.1 Margin of Safety

The margin of safety (MOS) is a required component of the TMDL, which accounts for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

An explicit margin of safety of 10% was used for North Creek to account for uncertainties in the methodologies used to determine sediment loadings.

An implicit margin of safety was chosen for the phosphorus TMDL because of conservative endpoint selection and modeling assumptions.

- The selection of the 0.06 mg/L endpoint concentration is protective of aquatic life. The endpoint concentration is the lowest measured instream TP concentration at an unimpaired monitoring station (2-NOR000.20).

- In the North Creek GWLF model, the TP contribution from the scrub/shrub land use category was considered a background load similar to evergreen forest. This shift reduced the TMDL load allocations from controllable sources.

- Although the GWLF model is often used without calibration, the GWLF model for North Creek was calibrated using observed data. As a result the background loads from forested and scrub/shrub land uses increased requiring greater reductions from NPS loads from all other land uses. Therefore, the calibrated model provided a conservative estimate of load allocations from controllable NPS sources in the North Creek TMDL.

## 7.2 Sediment TMDL Allocations

### 7.2.1 Overall Sediment Reduction Level to Meet the End Point

Reducing the sediment loading in the impaired watershed to the estimated TMDL endpoint is expected to restore support of the aquatic life use for the North Creek. The TMDL endpoint was estimated at 92.7 tons/year and the existing conditions sediment loading in the North Creek impaired watershed at 101.8 tons/year. **Table 7-1** indicates that an overall sediment reduction of 9.0% is necessary in the North Creek watershed to meet the endpoint. This overall sediment reduction level corresponds to a 42.8% reduction for all the *controllable* loads in the watershed (all the sources except sediment loads from forested/grassland lands and point sources).

**Table 7-1: Sediment Reductions in North Creek to Meet The Endpoint**

| Source | Land Use Type | Existing (tons/year) | Allocated (tons/year) | Percent Reduction |
|---|---|---|---|---|
| Land Sources | Grassland/Herbaceous | 3.83 | 3.83 | 0.0% |
| | Deciduous Forest | 29.19 | 29.19 | 0.0% |
| | Evergreen Forest | 7.31 | 7.31 | 0.0% |
| | Mixed Forest | 1.84 | 1.84 | 0.0% |
| | Pasture/Hay | 41.74 | 23.88 | 42.8% |
| | Cultivated Crop | 4.38 | 2.51 | 42.8% |
| | Developed, Low intensity | 0.59 | 0.34 | 42.8% |
| | Developed, Med Intensity | 1.30 | 0.74 | 42.8% |
| | Developed, High Intensity | 0.83 | 0.48 | 42.8% |
| | Developed, Open Space | 0.19 | 0.11 | 42.8% |
| **Instream Erosion** | - | 10.32 | 5.90 | 42.8% |
| **Point Sources** | Point Source Sediment | 0.30 | 5.44 | 0.0% |
| | Future Growth (2% of the TMDL) | - | 1.85 | - |
| **Margin of Safety** | 10% of the TMDL | | 9.27 | -- |
| | **Total** | **101.83** | **92.69** | **9.0%** |

### 7.2.2 Waste Load Allocation

There are two point sources, Envoy at the Village (VA0081639) and the Fork Union Military Academy STP (VA0024147), in the North Creek watershed contributing sediment to the stream. The wasteload allocated to each point source was based on design flow and the average total suspended solids concentration for each facility as shown in **Table 7-2**. Since the existing TSS load per year is less than the permitted annual sediment load for both facilities, there is no percent reduction required for the point sources. The wasteload allocation will be the permitted annual sediment loading per year.

| Table 7-2:. Sediment Wasteload Allocation for the North Creek Watershed | | | | |
|---|---|---|---|---|
| **Permit Number** | **Facility Name** | **Existing Sediment Load (tons/year)** | **Allocated Sediment Load (ton/year)** | **Percent Reduction** |
| VA0081639 | Envoy at the Village | 0.06 | 0.91 | 0.0% |
| VA0024147 | Fork Union Military Academy | 0.24 | 4.52 | 0.0% |
| | **Total** | **0.30** | **5.44** | 0.0% |
| Wasteload allocation includes 2% of the TMDL for Future Growth at 1.85 tons/year | | | | |

### 7.2.3 Load Allocation

**Table 7-3** details the load allocation for each nonpoint source. Since sediment loads from forested and grassland/herbaceous areas are considered background conditions, no reductions were assigned to these categories.

| Table 7-3: Sediment Load Allocations Summary for North Creek | | | |
|---|---|---|---|
| **Land Use/Source** | **Existing Load (ton/year)** | **Allocated Load (ton/year)** | **Percent Reduction** |
| Grassland/Herbaceous | 3.83 | 3.83 | 0.0% |
| Deciduous Forest | 29.19 | 29.19 | 0.0% |
| Evergreen Forest | 7.31 | 7.31 | 0.0% |
| Mixed Forest | 1.84 | 1.84 | 0.0% |
| Pasture/Hay | 41.74 | 23.88 | 42.8% |
| Cultivated Crop | 4.38 | 2.51 | 42.8% |
| Developed, Low intensity | 0.59 | 0.34 | 42.8% |
| Developed, Med Intensity | 1.30 | 0.74 | 42.8% |
| Developed, High Intensity | 0.83 | 0.48 | 42.8% |
| Developed, Open Space | 0.19 | 0.11 | 42.8% |
| Instream Erosion | 10.32 | 5.90 | 42.8% |
| **Total** | **101.53** | **76.13** | **25.0%** |

### 7.2.4 TMDL

The wasteload allocation, load allocation, margin of safety and the TMDL in tons/year for North Creek are summarized in **Table 7-4**. The wasteload allocation, load allocation, margin of safety and the TMDL in tons/day for North Creek are summarized in **Table 7-5**.

| Table 7-4: Sediment TMDL for North Creek (ton/year) | | | |
|---|---|---|---|
| **Wasteload Allocation[1]** | **Load Allocation** | **Margin of Safety (10%)** | **TMDL** |
| **7.29** | **76.13** | **9.27** | **92.69** |
| [1]Wasteload allocation includes 2% of the TMDL for Future Growth | | | |

| Table 7-5: Sediment TMDL for North Creek (ton/day) | | | |
|---|---|---|---|
| **Wasteload Allocation[1]** | **Load Allocation** | **Margin of Safety (10%)** | **TMDL** |
| **0.020** | **0.209** | **0.025** | **0.25** |
| [1]Wasteload allocation includes 2% of the TMDL for Future Growth | | | |

## *7.3 Phosphorus TMDL Allocations*

### 7.3.1 Overall TP Reduction Level to Meet the End Point

Reducing the phosphorus loading in the impaired watershed to the estimated TMDL endpoint is expected to restore support of the aquatic life use for North Creek. The TMDL endpoint was estimated at 426 pounds/year and the existing conditions TP loading in the North Creek impaired watershed at 785 pounds/year. **Table 7-6** indicates that an overall phosphorus reduction of 45.7% is necessary in North Creek watershed to meet the endpoint. This overall TP reduction level corresponds to a 77.8% reduction for all the *controllable* loads in the watershed.

| Table 7-6: TP Reductions in North Creek to Meet The Endpoint | | | | |
|---|---|---|---|---|
| **Source** | **Land Use Type** | **Existing (lbs/year)** | **Allocated (lbs/year)** | **Percent Reduction** |
| **Land Sources** | Grassland/Herbaceous | 6.8 | 6.8 | 0.0% |
| | Deciduous Forest | 20.5 | 20.5 | 0.0% |
| | Evergreen Forest | 4.4 | 4.4 | 0.0% |
| | Mixed Forest | 0.9 | 0.9 | 0.0% |
| | Pasture/Hay | 132.5 | 29.4 | 77.8% |
| | Scrub/Shrub | 5.3 | 5.3 | 0.0% |
| | Cultivated Crop | 1.3 | 0.3 | 77.8% |
| | Developed, Low Intensity | 6.4 | 1.4 | 77.8% |
| | Developed, Med Intensity | 14.3 | 3.2 | 77.8% |
| | Developed, High Intensity | 8.6 | 1.9 | 77.8% |
| | Developed, Open Space | 75.0 | 16.6 | 77.8% |
| **Groundwater** | - | 148.0 | 148.0 | 0.0% |
| **Point Sources** | Point Source TP | 361.1 | 178.8 | 50.5% |
| | Future Growth (2% of the Total Allocated Load) | - | 8.5 | - |
| | **Total** | **785.1** | **426.0** | **45.7%** |

## 7.3.2 Waste Load Allocation

There are two point sources, Envoy at the Village (VA0081639) and the Fork Union Military Academy STP (VA0024147), in the North Creek watershed contributing phosphorus to the stream. The wasteload allocated to these point sources was based on design flow and a TP concentration of 0.5 mg/L for each facility (**Table 7-7**). The wasteload allocation will be the permitted annual loading.

| Table 7-7:. TP Wasteload Allocation for the North Creek Watershed | | | | |
|---|---|---|---|---|
| **Permit Number** | **Facility Name** | **Existing TP Load (lbs/year)** | **Allocated TP Load (lbs/year)** | **Percent Reduction** |
| VA0081639 | Envoy at the Village | 49.1 | 30.1 | 38.8% |
| VA0024147 | Fork Union Military Academy | 312.0 | 148.7 | 52.3% |
| | **Total** | **361.1** | **178.8** | **50.5%** |
| Wasteload allocation includes 2% of the TMDL for Future Growth at 8.5 lbs/year | | | | |

### 7.3.3 Load Allocation

**Table 7-8** details the load allocation for each nonpoint source. Since TP loads from forested, grassland/herbaceous, scrub/shrub areas and groundwater are considered background conditions, no reductions were assigned to these categories.

**Table 7-8: TP Load Allocations Summary for North Creek**

| Land Use/Source | Existing Load (lbs/day) | Allocated Load (lbs/day) | Percent Reduction |
|---|---|---|---|
| Grassland/Herbaceous | 6.8 | 6.8 | 0.0% |
| Deciduous Forest | 20.5 | 20.5 | 0.0% |
| Evergreen Forest | 4.4 | 4.4 | 0.0% |
| Mixed Forest | 0.9 | 0.9 | 0.0% |
| Pasture/Hay | 132.5 | 29.4 | 77.8% |
| Scrub/Shrub | 5.3 | 5.3 | 0.0% |
| Cultivated Crop | 1.3 | 0.3 | 77.8% |
| Developed, Low intensity | 6.4 | 1.4 | 77.8% |
| Developed, Med Intensity | 14.3 | 3.2 | 77.8% |
| Developed, High Intensity | 8.6 | 1.9 | 77.8% |
| Developed, Open Space | 75.0 | 16.6 | 77.8% |
| Groundwater | 148.0 | 148.0 | 0.0% |
| **Total** | **424.0** | **238.7** | **43.7%** |

### 7.3.4 TMDL

The wasteload allocation, load allocation, margin of safety and the TMDL in pounds/year for North Creek are summarized in **Table 7-9**. The wasteload allocation, load allocation, margin of safety and the TMDL in pounds/day for North Creek are summarized in **Table 7-10**.

**Table 7-9: Total Phosphorus TMDL for North Creek (lbs/year)**

| Wasteload Allocation[1] | Load Allocation | Margin of Safety | TMDL |
|---|---|---|---|
| **187.3** | **238.7** | **IMPLICIT** | **426.0** |
| [1]Wasteload allocation includes 2% of the TMDL for Future Growth | | | |

**Table 7-10: Total Phosphorus TMDL for North Creek (lbs/day)**

| Wasteload Allocation[1] | Load Allocation | Margin of Safety | TMDL |
|---|---|---|---|
| **0.513** | **0.654** | **IMPLICIT** | **1.167** |
| [1]Wasteload allocation includes 2% of the TMDL for Future Growth | | | |

## 7.4 Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7 (c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that designated uses are protected throughout the year, including vulnerable periods.

In the case of North Creek, the primary stressors resulting in the benthic impairment in the river are excessive sediment and phosphorus loading, which has led to degradation of habitat and the impairment of benthic habitat. Since sediment and phosphorus loadings occur throughout the year and their impact on benthic invertebrates are often a function of cumulative loading, it is appropriate to consider sediment and phosphorus loading on an annual basis. Therefore, TMDL allocations were developed based on average annual loads determined from the eight year simulation period performed using the GWLF model.

## 7.5 Consideration of Seasonal Variability

Seasonal variations involve changes in stream flow and sediment loading as a result of hydrologic and climatological patterns. Seasonal variations were explicitly incorporated in the modeling approach for these TMDLs. GWLF is a continuous simulation model that incorporates seasonal variations in hydrology and sediment loading by using a daily time-step for water balance calculations. Therefore, the eight year simulation performed with GWLF adequately captures seasonal variations.

# 8.0 TMDL Implementation

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources in the stream. For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA, which includes a set aside for future growth, pursuant to 40 CFR 122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ TMDL project staff or at http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/ipguide.pdf. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

## *8.1 Staged Implementation*

In general, Virginia intends for the required BMPs to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Among the most efficient sediment and phosphorus BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement. The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

## *8.2 Linking the Pollutant Reductions*

There are two TMDLs developed for North Creek, one for sediment and the other for total phosphorus. In developing the implementation plan for North Creek, actions that will reduce phosphorus will in turn likely help in the reduction of sediment and vice versa. Many best management practices reduce many more than one pollutant, so in the development of the implementation plan, attention should be paid to select practices that are effective at reducing both pollutants.

## *8.3 Link to Ongoing Restoration Efforts*

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. Examples of sediment and phosphorus pollution reduction practices include:

- Agricultural Best Management Practices (BMP) includes practices to reduce or eliminate soil loss, prevent runoff, and provide for the proper application rates of nutrients to cropland, vegetated buffer strips at the edge of crop fields, conservation tillage, strip cropping, animal waste management, and stream bank fencing
- Urban Best Management Practices which include erosion and sediment BMPs to control runoff from areas under development and stormwater controls in developed areas. These practices are applied across a broad spectrum from industrial, commercial, and residential facility construction sites to the management of lawns and open spaces, reducing nutrient runoff.
- Stormwater Management controls including Low Impact Development (LID)
- Upgrades made to wastewater treatment plants, many which are performed during the installation of biological nutrient removal (BNR) process to meet Bay nutrients allocations
- Septic system maintenance

- Stream Buffers. Streamside forest to reduce or remove excess nutrients and sediment from surface runoff and shallow groundwater and aid in shading streams to optimize light and temperature conditions for aquatic plants and animals.

## *8.4 Reasonable Assurance for Implementation*

### 8.4.1 Follow-Up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

### 8.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the state's Water Quality Management Plans. The WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's web site under http://www.deq.virginia.gov/Portals/0/DEQ/LawsAndRegulations/CitizenBoards/WaterBoard/WaterPublicCommentPolicyAtBoardMeetingsfinal2192009.pdf

### 8.4.3 Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the

Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

### 8.4.4 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, the current designated use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of the contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at:

http://lis.virginia.gov/cgi-bin/legp604.exe?000+reg+9VAC25-260-10

# 9.0 Public Participation

The development of the North Creek benthic TMDL would not have been possible without public participation. One technical advisory committee (TAC) meeting and two public meetings were held. The following is a summary of the meetings.

**Public Meeting No. 1**. The first public meeting was held April 7th, 2011 at the Central Virginia Community Health Center in New Canton to present the process for TMDL development, the North Creek benthic impaired segment, and data that caused the segment to be on the 303(d) list, data and information needed for TMDL development. Six people attended this meeting. Copies of the presentation were available for public distribution. This meeting was publicly noticed in the *Virginia Register*. No written comments were received during the 30-day comment period. No written comments were received.

**TAC Meeting No. 1.** The first TAC meeting was held on July 28th, 2011 at the Buckingham USDA Service Center in Buckingham, VA to present and review the steps and the data used in the development of the benthic TMDLs for the North Creek listed segment, as well as the potential most probable stressor and technical approach. Five people attended this meeting. No written comments were received.

**Public Meeting No. 2**. The second (and final) public meeting was held in on October 7th, 2011 at the Arvonia Firehouse in Arvonia, VA to present and discuss the allocations for North Creek. Fourteen people attended this meeting. Copies of the presentation and the draft TMDL report were available for public distribution. The meeting was public noticed in *The Virginia Register.* No written comments were received.

**Final Public Comment Period.** In early 2014, there were changes made to some of the model inputs and outputs. Accordingly, a public comment period from April 7, 2014 to May 7, 2014 was held. No comments were received.

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